OFFICIAL HISTORY OF THE INDIAN ARMED FORCES
IN THE SECOND WORLD WAR 1939-45

MEDICAL SERVICES

Medicine, Surgery and Pathology

Edited by
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. . . to all Who Served

GENERAL PREFACE

The present volume is the second in the medical series of the Official History of the Indian Armed Forces in the Second World War. This series has been edited by Lieut.-Colonel B. L. Raina, AMC, under whose close supervision the work has been completed by the Medical Sub-Section of the Combined Inter-Services Historical Section.

The Historical Section was established in 1946 for the purpose of recording the part played by the armed forces of the pre-partition India in the various theatres of the Second World War. Even after the partition of India, the two Dominions, India and Pakistan, agreed to maintain the Historical Section as a joint organisation. But for this it would not have been possible to complete this task.

An endeavour has been made in these volumes to reconcile the requirements of the specialist with the needs of the general reader. The main purpose is to describe the work performed by the Indian Army Medical Services during the six momentous years of the world war. We shall be happy if the present series of volumes would inspire the Medical Services to emulate the achievements of the last decade and seek inspiration from this record to excel the past.

I am thankful to Lieut.-General D. N. Chakravarti for writing a Foreword to this volume. I must also express my sense of gratitude and appreciation to Lieut.-Colonel B. L. Raina for the manner in which he has accomplished a difficult task.

New Delhi, 1955. Bisheshwar Prasad.

MEDICAL SERIES.

FOREWORD

This volume is the second in the medical history ~~series and deals~~ with medicine, surgery and allied subjects. It is based mainly on the observations made and experience gained in the eastern theatre, as also on the researches conducted in important diseases encountered in Burma and South East Asia. No detailed medical history of the wars in which Indian troops took part in the past is available. It is, therefore, gratifying to note that in this series it has been possible to record the results of the co-operative efforts of the Medical Services of the Indian Armed Forces of undivided India (now India and Pakistan).

Generally speaking, war medicine involves no new basic concepts, but the speedy development of the organisation and technique suitable for field conditions lends it an importance unknown to civil life. War brings in its wake many new problems and many of the old problems assume a new orientation which is particularly marked in the case of medical problems. The pace of research and development is considerably accelerated under the stress of war. It is commonly accepted that conservation of manpower from sickness and wounds and maintenance of the morale of the fighting forces are as important agents as strategy, tactics, weapons and vehicles for achieving victory. This is where the medical services fit into the pattern. Even though the medical problems met with in armed forces do not basically differ from those in civilian practice, the extent of some of these becomes wider and new problems arise under the stress of war.

It is interesting to observe that the British Official History of World War I discussing the *Diseases of the War* opens with the remark: "During the war, popular attention finds its chief interest in the number of wounded and concerns itself much less with the amount of sickness amongst the troops, although in every war of which we have records from the days of Sennacherib onwards the inefficiency from disease has outnumbered many times the losses from killed and wounded". The comparative incidence of sickness and war wounds, especially in the eastern theatre, has once again confirmed the truth of the above observation. For every one soldier wounded on the Indo-Burma front, 204 were sick in 1942 and 142 in 1943. By 1945 the ratio of battle and non-battle casualties was reduced to 1:13. The problems of fighting diseases and tending the wounds were as complex as they were numerous. The preparations to solve these problems left much to be desired.

At the outbreak of the war, the Indian Army employed only 87 specialists. The specialist cadre did not include consultants, advisers, or specialists in neurology, malariology and nutrition. The dermatologists looked after both skin and venereal disease cases. By August 1945, the number of specialists was increased to 1,576. A number of consultants and advisers were appointed in different branches of medicine and surgery. Specialist units and hospitals were provided to look after

the casualties. Hospital beds were increased from 12,821 in 1939 to 169,981 in 1945. It is estimated that over 50,00,000 cases were treated in these hospitals. It has not been possible to analyse the data from the large number of hospital case sheets; attempt has, however, been made to record in this volume some of the observations made and research done during the war. In the range of application of science to the men and equipment employed, and in its global aspect enveloping different terrains in various countries, World War II can be truly said to be unique.

It is true that one can be better prepared for a subsequent war in the light of the experience gained from a conflict of the magnitude of World War II, provided it is known that the next war will also be fought on similar lines. But, unfortunately, no two wars have been fought on similar lines. The nature of the next conflict, if ever it occurs, can hardly be predicted in view of the rapid advance of science, and it is hardly possible to say whether any of the lessons learnt from the earlier war would be put into effective use in the pattern of a new war. But every progress in science lay the foundation for further advancement.

It is hoped that the account contained in this volume will be of very great interest to the medical services of the armed forces and also to the medical profession in general. It may also give an insight into the importance of the medical profession to the lay reader. A very high degree of efficiency was achieved in regard to modern methods of preventive medicine, treatment, evacuation of casualties, maintenance of morale of fighting forces and research in new medical problems during World War II. In the eastern theatre of war, long known for its unhealthy nature, the control of malaria was an achievement which medical services can well be proud of. The whole campaign would have been impossible but for the very important part played by the medical services in this region. The elimination of malaria and dysentery, which had decimated armies in the past, is no mean achievement. The use of suppressive mepacrine, sulpha group of drugs and penicillin was an important factor in reducing the morbidity and mortality rates of the fighting forces.

Medical science is dynamic and some of the achievements of World War II may soon have, or may become, out of date, but the medical profession, basing its experiences on the past, must keep a vigilant watch on the present and must continue its efforts to achieve the maximum efficiency in the light of modern research. Flexibility of plans and improvisation, and vigilant outlook, are essential for success during the war, and any delay in action or conservatism of outlook is fraught with danger. It is, therefore, very important that every administrative medical officer should be conversant with the experiences recorded in this volume.

A Sub-Section under the Deputy Director of Hygiene and Pathology (DDH & P), Medical Directorate, GHQ (India), was made responsible in February 1941 for the collection of material of historical interest. Instructions were issued to medical units to mark their war diaries suitably and to conserve all letters of policy received by them

from time to time. An executive committee was formed in 1944 consisting of the DGIMS, the DMS, the PMO, RIN, and the PMO, Air Headquarters. The Director of the Combined Inter-Services, Historical Section, was included in the committee. Lieut.-Colonel J. G. Thomson, IMS was appointed as Chief Collator and Editor in July 1945. By May 1946 the staff was collected and three officers joined the section. The Chief Collator and Editor visited various theatres of war in Burma and South East Asia and also toured the various commands to collect material.

The section continued to be under the control of the Medical Directorate until the end of 1946, when it was transferred to the Combined Inter-Services Historical Section. The DMS, and later the DGAFMS, however, retained responsibility for the policy, direction and general supervision in medical matters of the scheme of medical history. The Medical Section then became a Sub-Section of the Combined Inter-Services Historical Section, and was placed under the control of the Supreme Commander and later the Joint Defence Council after 15th August, 1947. From the beginning till the end of the year 1947, the section was actively employed in collecting, sorting and indexing notes, papers and documents and collating them into preliminary narratives. The Joint Defence Council decided in March 1948 that this section should work under the direct administrative control of the Ministry of Defence, Government of India, for both India and Pakistan. It was obvious from the very beginning that a considerable re-organisation and expansion of the staff was necessary to undertake the preparation of a detailed history of this nature. The Joint Defence Council, therefore, sanctioned an establishment consisting of one Editor and five Narrators. Lieut.-Colonel B. L. Raina, AMC was appointed the Editor on 1st January 1948.

For the preparation of this volume it has been constantly necessary to draw upon the knowledge and experience of many administrative officers, consultants, advisers and specialists, who served in India during the war. This assistance was forthcoming readily and has been of considerable advantage as without it this history would have been difficult to complete.

A great step forward was taken in the exchange of information between the American, the British and the Commonwealth historians, when a conference of the medical historians was held in 1946 to explore the possibilities of collaboration. It will be seen that the Indian Medical History is invariably linked with the Commonwealth histories, and medical problems and progress are essentially the same the world over. The Conference recommended the formation of a permanent Official Medical Historians Liaison Committee to act as a central agency for the free interchange of information between the medical historians, and to provide facilities for meetings to review progress and to hold consultations on technical questions and to consider solutions of such problems as relate to the correlation of data, avoidance of overlap and methods of presentation. Meetings of this committee were subsequently held at Ottawa 1947, Oxford 1948, Canberra 1949 and

New Delhi 1952. These meetings were attended by the medical historians of the Commonwealth Countries and the United States of America (or their representatives) and proved to be of immense value.

An Advisory Committee in India was established by the end of 1948 and met at frequent intervals in Simla and Delhi to guide the preparation of the history. These meetings were of great help in preparing the different volumes. Several members of the committee had to be changed due to the exigencies of service and to all those, including the past Chairmen, Lieut.-General K. S. Master, MC, and Lieut.-General D. R. Thapar, we owe a deep debt of gratitude for their valuable services ungrudgingly rendered. We are also grateful to the many consultants and officers of the IMS and RAMC and other collaborators for their ideas, contributions and reviews of the various volumes. Finally, I must express my thanks to Dr. Bisheshwar Prasad, the Director of the Combined Inter-Services Historical Section, under whose administrative control and overall guidance this history has been compiled.

Lieut.-General,
Chairman, Medical History Advisory Committee.

PREFACE

This volume deals with medicine, surgery, pathology and kindred subjects. The discussion in the narratives is mainly limited to the observations made in India, Burma and South East Asia during the war. Only those diseases and disorders are mentioned here which had led to relatively larger number of casualties or those which assumed special importance. Even within this limited field, all important problems of war medicine have not been discussed, as the account given is necessarily limited by the amount of information available. It must, therefore, be supplemented by the accounts published during and after the war, particularly the volumes prepared by USA and the Commonwealth countries. The six volumes of *Bulletin of War Medicine* published by the Medical Research Council in London (with the co-operation of the Bureau of Hygiene and Tropical Diseases) during 1940-46, for example, will provide a valuable and critical summary of the articles published in the medical and scientific journals during the war. This bulletin has been of great help in compiling this volume.

Although the discussion in the following pages relates generally to the work done by the officers of the armed forces, the work of others and accounts contained in medical literature have also been incorporated. No attempt has been made to prune such accounts in the interests of uniformity of presentation and the original description given by each contributor has been preserved. This has resulted in meticulous details in some chapters, whereas in others the subject has been briefly discussed. This is so not only because of the extent of the available information, but also owing to the importance and the extent of the work done in some subjects during the war. Some repetition may also be found, when the same problem is discussed from a different standpoint.

Some of the important medical problems like malaria, nutrition and preventive medicine are dealt with in other volumes of the medical history.

In this volume, chapters II to XXVI deal with the diseases which are generally listed under the title of general medicine. The chapters on dermatology, neurology, psychiatry and venereology have also been included in this group. Chapters XXVII to XXXVIII deal with general surgical subjects, and chapters XXXIX to XLI comprise of aid given by civilian institutions, biochemistry and pathology services. In the first chapter general statistics are discussed and comments on a few important diseases and administrative problems have been made. A list each of technical instructions and important pamphlets issued by the Medical Directorate during the war is given at the end of the volume.

It was originally planned to discuss surgical problems in some detail. This unfortunately could not be done, as the contributors of this section were not able to complete the work due to unavoidable circumstances.

The contributions have been mainly prepared by consultants, advisers and specialists, who had adequate opportunities to observe the conditions they discuss.

I owe a special debt of gratitude to all the contributors and collaborators as also to the members of the Medical History Advisory Committee, who accepted to write or helped in writing the different contributions.

Dr. C. G. Pandit, Lieut.-Colonel M.L. Ahuja, Brigadier S. Narain, Colonel B. L. Kapur, Colonel M. S. Rao, Colonel R. D. Ayyar, Colonel C. C. Kapila and Lieut.-Colonel P. N. Bardhan have very kindly read the different sections of the manuscript and have given valuable suggestions. Dr. E. K. K. Pillai rendered immense help in the preparation of the manuscript and was associated in the editorial work.

Great assistance in the preparation of this volume was given by Dr. N. N. Ghosh, whose sudden death deprived the Historical Section of the services of a young and efficient officer.

I acknowledge the courtesy of the *Journal of Neurology, Neuro-surgery and Psychiatry*, *Quarterly Journal of Medicine*, *British Journal of Venereal Diseases*, World Health Organisation, British Medical Association and the Clarendon Press, Oxford for the permission to use blocks of illustrations which have already appeared in their publications and to the authors and their publishers whose work has been quoted in the text. Acknowledgement is also made to GHQ West African Forces for incorporating their observations on stibophen, anthiomaline and tartar emetic in the treatment of schistosomiasis. It has not been possible to obtain prior consent of all the authors from whose articles excerpts have been made, and it is trusted that this general acknowledgement will be accepted by them as an earnest of our indebtedness to them.

Finally I wish to avail of this opportunity to express my gratitude to the publishers for their efficient service and prompt assistance.

B. L. R.

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ABBREVIATIONS

ADC	...	Army Dental Corps.
ADDS	...	Assistant Director of Dental Services.
ADH	...	Assistant Director of Hygiene.
ADH & P	...	Assistant Director of Hygiene and Pathology.
ADM	...	Assistant Director of Malariology.
ADMS	...	Assistant Director of Medical Services.
ADP	...	Assistant Director of Pathology.
ADS	...	Advanced Dressing Station.
AFNEI	...	Allied Forces Netherlands East Indies.
AI(I)	...	Army Instruction (India).
ALFSEA	...	Allied Land Forces South East Asia.
AMC	...	Army Medical Corps.
AR	...	Analytical Reagent.
AU	...	American Unit.
BAL	...	British Anti-Lewisite.
BC	...	British Cadre.
b.d.	...	Twice daily.
b.d.p.c.	...	Twice daily after meals.
BGH	...	British General Hospital.
BLA	...	British Liberation Army.
BMH	...	British Military Hospital.
BMR	...	Basal Metabolic Rate.
BOR	...	British Other Rank.
BP	...	British Pharmacopoeia.
BS	...	British Service.
BSIR	...	Board of Scientific and Industrial Research.
BSR	...	Blood Sedimentation Rate.
BT	...	Benign Tertian.
(BT)	...	British Troops.
(C)	...	Combined.
c.c.	...	Cubic centimeter.
CCS	...	Casualty Clearing Station.
CDRE(I)	...	Chemical Defence Research Establishment (India).
CGH	...	Combined General Hospital.
CI	...	Colour Index.
cm.	...	Centimeter.
CMH	...	Combined Military Hospital.
c.mm.	...	Cubic millimeter.
CRI	...	Central Research Institute.
CSF	...	Cerebrospinal Fluid.
Cu	...	Cubic.
DAAG	...	Deputy Assistant Adjutant General.
DADP	...	Deputy Assistant Director of Pathology.
DBP	...	Di-butyl Phthalate.
DDDS	...	Deputy Director of Dental Services.
DDH & P	...	Deputy Director of Hygiene and Pathology.
DDMS	...	Deputy Director of Medical Services.

DDT	...	Dichloro-Diphenyl-Trichlorethane.
DGAFMS	...	Director General Armed Forces Medical Services.
DGIMS	...	Director General Indian Medical Service.
DMP	...	Di-methyl Phthalate.
DMS	...	Director of Medical Services.
EA	...	Enemy Action.
EBI	...	Emetine Bismuth Iodide.
FA	...	Fatty Acid.
g.	...	Gramme.
GHQ	...	General Headquarters.
GS	...	General Service.
GSW	...	Gun Shot Wound.
Hb.	...	Haemoglobin.
IADC	...	Indian Army Dental Corps.
IAMC	...	Indian Army Medical Corps.
IAO	...	India Army Order.
IAOC	...	Indian Army Ordnance Corps.
IBGH	...	Indian Base General Hospital.
IC	...	Indian Cadre.
ICO	...	Indian Commissioned Officer.
IEME	...	Indian Electrical and Mechanical Engineers.
IGH	...	Indian General Hospital.
IMD	...	Indian Medical Department.
IMH	...	Indian Military Hospital.
IMS	...	Indian Medical Service.
IMS(D)	...	Indian Medical Service (Dental).
IOR	...	Indian Other Rank.
IS	...	Indian Service.
(IT)	...	Indian Troops.
IU	...	International Unit.
JCO	...	Junior Commissioned Officer.
Kg.	...	Kilogramme.
KHP	...	King's Honorary Physician.
lb.	...	Pound.
LD	...	Leishman-Donovan.
L/T	...	Light Type.
L/W	...	Light Weight.
MCH	...	Mean Corpuscular Haemoglobin.
MCHC	...	Mean Corpuscular Haemoglobin Concentration.
MCV	...	Mean Corpuscular Volume.
MDS	...	Main Dressing Station.
mEq/L	...	Milli Equivalent Litres.
MFTU	...	Malaria Forward Treatment Unit.
mg.	...	Milligramme.
mm.	...	Millimeter.
MME	...	Medical Mobilisation Equipment.
MNO	...	Mental Nursing Orderly.
MRC	...	Medical Research Council.

MT	...	Malignant Tertian.
NAB	...	Neosalvarsan (Novarsenobillon).
NC(E)	...	Non-Combatant (Enrolled).
NCO	...	Non-Commissioned Officer.
NEA	...	Non-Enemy Action.
NFDR	...	Non-Fat Dry Residue.
NYD	...	Not Yet Diagnosed.
oz.	...	Ounce.
pH	...	Symbol representing Hydrogen Ion Concentration.
PLME	...	Price List of Medical Equipment.
PMO	...	Principal Medical Officer.
POW	...	Prisoner/s of War.
PVMS	...	Priced Vocabulary of Medical Stores.
q.d.s.	...	Four times a day.
Q.S.	...	As much as required.
RAF	...	Royal Air Force.
RAMC	...	Royal Army Medical Corps.
RAP	...	Regimental Aid Post.
RAPWI	...	Recovered Allied Prisoners of War and Internees.
RBC	...	Red Blood Cell.
RIAF	...	Royal Indian Air Force.
RIASC	...	Royal Indian Army Service Corps.
RIN	...	Royal Indian Navy.
RMO	...	Regimental Medical Officer.
SEAC	...	South East Asia Command.
STO	...	Special Treatment Orderly.
TAB	...	Vaccine which protects against typhoid, paratyphoid A and paratyphoid B.
TB	...	Tuberculosis.
t.d.s.	...	Three times a day.
t.d.s.p.c.	...	Three times a day after meals.
μ	...	Micron.
USA	...	United States of America.
USP	...	United States Pharmacopoeia.
VCO	...	Viceroy's Commissioned Officer.
VD	...	Venereal Disease.
WAC(I)	...	Women's Auxiliary Corps (India).
WBC	...	White Blood Cell.
WR	...	Wassermann Reaction.

GUIDE TO FOOTNOTES

Footnotes have been numbered serially on each page. They can be classified in three categories, *viz.*, (i) explanatory notes, (ii) cross references, and (iii) the sources from which the material has been collated.

To assist the reader who may wish to consult the original sources, the explanation of abbreviations, in respect of the type of documents used in footnotes, is given below:—

H	... ...	Combined Inter-Services Historical Section Library Document.
H(M)	... ...	Combined Inter-Services Historical Section Medical Library Document.

The H(M) documents are preceded by a symbol or symbols and a number. The meaning of these symbols is as follows:—

Symbol		*Subject of the file or document*
A ...	...	Administration, organisation and liaison.
F ...	...	Files relating to the period after June 1941.
FZ ...	...	Files relating to the period before June 1941.
H ...	...	History.

CHAPTER I

Diseases during the War—General Aspects

During the Second World War the medical services in India had to function under difficult circumstances and frequently changing conditions. The numerous difficulties relating to personnel and equipment remained serious throughout the period of hostilities. In the early years of the war, most of the trained personnel and reserve medical supplies were allocated to the Middle East, Iraq and Persia. Japanese victories in the South East Asia and the ultimate withdrawal of the Indian and British troops along with about 500,000 civilians from Burma in 1942, created a very grave situation. The sickness rate on the Indo-Burma front in 1943 rose to 1,196·10 per 1,000. Hospitals were taxed to the utmost capacity, as the accommodation available was about one-sixth of the casualties received. The medical services were thus strained almost to breaking point.

Subsequent fighting on the Indo-Burma front was carried out in a terrain notorious for ill health and disease. It contained some of the highly malarious regions of the world with annual rainfall as high as 200 inches. The successful campaign in such an area was made possible only by careful planning and tremendous effort. A number of specialist units and hospitals were raised. The high sickness rate involved the employment of a large number of specialists, advisers and consultants. The number of specialists available being insufficient, arrangements to train more to meet the deficiency had to be made. The policy of providing treatment facilities as far forward as possible in the field, with the object of ensuring early treatment and conservation of manpower, reduced the number of casualties evacuated to the base. This made it necessary to deploy lightly equipped 200 and 400 bedded hospitals, malaria forward treatment units (MFTUs), specialist treatment centres, convalescent depots and rehabilitation centres. Research teams were established to study urgent problems. The resources of the whole country including different Government departments and civilian institutions were harnessed. By 1945, 1,163 medical units, including 374 specialist units, had been raised, hospital beds were increased (from 13,321 in 1939) to 197,539 and 9,393 medical officers, 4,104 nurses and 152,469 other ranks were serving in the medical services.

SICKNESS AND WAR WOUNDS

A study of morbidity and mortality figures of World War II once again shows that many more men are disabled by sickness than by

enemy action. The striking wastage of manpower by disease is illustrated by the high ratio of sickness to war wounds, especially on the Indo-Burma front.

TABLE I

Non-battle and battle casualties for all forces (Indian, British, East African and West African) on Indo-Burma front, Burma and South East Asia (excluding Ceylon).

	Non-battle casualties rate per 1,000*		Battle casualties rate per 1,000		Actual number		Ratio of battle casualties to non-battle casualties*
	Admission	Death	Admissoin	Death	Non-battle casualties	Battle casualties	
1942	921·14	7·48	4·51	...	178,139	872	1 : 204
1943	1,196·10	4·74	8·40	0·38	531,719	3,735	1 : 142
1944	1,040·91	5·91	47·43	2·18	541,575	24,680	1 : 22
1945†	384·13	1·62	29·19	1·25	213,047	16,188	1 : 13

The average ratio of war wounds to sickness (taking into consideration years of active operations only) was about 1 : 67. The ratio of mortality due to war wounds and that due to sickness in different theatres was on an average 1 : 18, the highest being 1 : 36 in Persia and Iraq Force during 1941. The case mortality amongst the war wounded (deaths amongst those admitted for war wounds) on the Burma front during 1942-45 varied from 4·0 to 4·7 per cent. The case mortality amongst the war wounded in Egypt, Western Desert and North Africa, Sudan and Eritrea and Persia and Iraq Force was 0·3-13·0 per cent, 0·9-8·3 per cent. and 1·6 per cent. respectively.

It will be apparent that for every soldier wounded on the Indo-Burma front 204 were sick in 1942 and 142 in 1943. The results of preventive measures, especially against malaria, are reflected in the ratio of battle and non-battle casualties in 1944 and 1945, when the ratios came down to 1 : 22 and 1 : 13 respectively.

The ratio of casualties due to enemy action and non-enemy action in Ceylon was high (in 1945 as high as 1 : 7,264), for the obvious reason that it was not a theatre of active operations. The average ratio in Ceylon during 1942-45 was 1 : 2,872.

*Approximately 96 per cent. of non-battle casualties were due to sickness and the remaining mostly due to accidental injuries.

†January to September only.

TABLE II

Relationship between casualties caused by enemy action (EA) and non-enemy action (NEA).

	VCOs and IORs			BORs			Indian troops (all ranks)		
	Casualties EA	Casualties NEA	Ratio of EA to NEA	Casualties EA	Casualties NEA	Ratio of EA to NEA	Casualties EA	Casualties NEA	Ratio of EA to NEA
Indo-Burma front									
Burma and SEAC (excluding Ceylon)									
1942 ...	606	98,843	1 : 163	209	47,357	1 : 227	640	127,235	1 : 199
1943 ...	2,631	297,597	1 : 113	805	104,323	1 : 130	2,758	418,664	1 : 152
1944 ...	14,157	304,224	1 : 21	8,042	109,579	1 : 14	14,655	388,914	1 : 26
1945*	10,198	121,040	1 : 12	3,833	43,970	1 : 11	10,377	143,775	1 : 14
Ceylon									
1942 ...	10	14,049	1 : 1,405	67	14,602	1 : 218	10	14,096	1 : 1,410
1943 ...	19	17,262	1 : 908	8	13,974	1 : 1,747	19	17,322	1 : 912
1944 ...	6	11,355	1 : 1,893	7	6,843	1 : 978	6	11,409	1 : 1,901
1945 ...	1	7,258	1 : 7,258	1	4,173	1 : 4,173	1	7,264	1 : 7,264
Egypt, Western Desert and North Africa									
1939 ...	...	1,649	...	...	...	...	...	2,117	...
1940 ...	...	3,890	...	...	...	...	...	5,425	...
1941† ...	910	7,026	1 : 8	...	181	...	940	10,341	1 : 11
1942 ...	1,892	34,626	1 : 18	7	176	1 : 25	2,051	45,784	1 : 22
1943 ...	2,067	27,622	1 : 13	7	460	1 : 66	2,119	36,395	1 : 17
1944 ...	450	16,146	1 : 36	2	321	1 : 160	464	19,403	1 : 42
1945 ...	23	8,809	1 : 383	...	65	...	23	11,023	1 : 479

* January to September only.

† September to December only.

TABLE II—(*Contd.*)

	VCOs and IORs			BORs			Indian troops (all ranks)		
	Casualties EA	Casualties NEA	Ratio of EA to NEA	Casualties EA	Casualties NEA	Ratio of EA to NEA	Casualties EA	Casualties NEA	Ratio of EA to NEA
Sudan and Eritrea									
1940* ...	16	937	1 : 59	...	221	...	16	1,091	1 : 68
1941 ...	1,977	4,299	1 : 2	107	1,412	1 : 13	2,030	6,015	1 : 3
1942 ...	12	3,405	1 : 284	...	4	...	12	4,367	1 : 364
1943† ...	...	414	...	...	...	...	...	520	...
Persia and Iraq Force									
1939 ...	...	19	...	...	...	...	...	19	...
1940 ...	...	44	...	...	...	...	...	45	...
1941 ...	181	26,030	1 : 144	51	10,112	1 : 198	185	32,570	1 : 176
1942 ...	69	55,939	1 : 811	25	36,101	1 : 1,444	79	73,372	1 : 929
1943 ...	129	63,817	1 : 495	43	34,975	1 : 813	135	82,578	1 : 612
1944 ...	62	30,043	1 : 485	8	10,375	1 : 1,297	63	37,441	1 : 594
1945 ...	46	17,295	1 : 376	4	6,121	1 : 1,530	48	21,433	1 : 446
Aden and Scotra									
1940 ...	...	1,132	...	...	...	...	...	1,336	...
1941 ...	1	1,263	1 : 1,263	...	...	...	1	1,620	1 : 1,620
1942 ...	1	1,447	1 : 1,447	...	...	...	1	1,769	1 : 1,769
1943 ...	17	1,324	1 : 779	...	...	...	17	1,597	1 : 939
1944 ...	1	976	1 : 976	...	...	...	1	1,256	1 : 1,256
1945 ...	..	711	...	...	...	...	...	943	...

* September to December only

† January to September only.

It is interesting to observe that in 1943 and 1944, on the Indo-Burma front statistically every soldier was more than once in hospital, admission rates being 1,196·10 and 1,040·91 per 1,000 respectively.

The figures also reveal that in 1944 (the year of highest admission rate due to war wounds) in the Indo-Burma theatre of operations, out of each group of 1,000 soldiers about 48 were wounded, and of these 48 wounded less than 3 died of war wounds. In 1943 (the year of low war wound admission rate) about 9 of every 1,000 soldiers were admitted with war wounds and of these less than one died of injuries due to enemy action.

The relationship of casualties due to enemy and non-enemy action in Egypt, Western Desert and North Africa (except for 1945) varied from 1 : 11 to 1 : 42. During 1945, the ratio was 1 : 479. This relatively high rate of sickness as compared to war wounds during 1945, was due to the fact that operational activities had practically ceased. It may be added that the ratio would have been more or less like that of Ceylon, but due to decreased rate of general morbidity the figure of sickness was only 479 times of the war wounds.

In Sudan and Eritrea the ratio of war wounds to sickness was 1 : 68 in 1940, 1 : 3 in 1941 and 1 : 364 in 1942.

The ratio of war wounds to sickness in Persia and Iraq Force was consistently high, 1 : 176 in 1941, 1 : 929 in 1942, 1 : 612 in 1943, 1 : 594 in 1944 and 1 : 446 in 1945.

The average ratio of war wounds to sickness in Aden and Scotra was 1 : 1,396 (the highest figure being 1: 1,769 in 1942). This was due to the area being a non-operational one like Ceylon.

AVERAGE CONSTANTLY SICK

The daily average numbers of constantly sick in Burma and SEAC, Ceylon, Sudan and Eritrea, Egypt, Western Desert and North Africa, Persia and Iraq Force were 28, 4, 14, 6 and 26 per 1,000 respectively.

Considering the years with highest figures it may be inferred that on an average about 12,488 beds in the hospitals were occupied daily by VCOs and IORs in Burma and SEAC (excluding Ceylon) in 1943. In other words, 47 soldiers out of every 1,000 were in the hospitals during the year. The highest rate of beds occupied in Ceylon was 5·5 per 1,000 in 1944, in Sudan and Eritrea 22 per 1,000 in 1941, in Egypt, Western Desert and North Africa 8·2 per 1,000 in 1945 and in Persia and Iraq 30·6 per 1,000 during 1942. These rates are for active operational years on various fronts.

TABLE III

Average number and rate per 1,000 of patients daily under treatment in hospitals.

Theatre of operations	VCOs and IORs	
	Average daily number under treatment in the year	Rate per 1,000
Indo-Burma front		
Burma and SEAC (excluding Ceylon)		
1943	12,487·92	46·96
1944	10,715·17	33·80
1945 (January to September) ...	475·97	1·55
Ceylon		
1942	615·00	4·1
1943	922·34	4·0
1944	444·58	5·5
1945	395·13	2·8
Sudan and Eritrea		
1940 (September to December) ...	311·25	22·5
1941	340·65	21·8
1942	41·40	8·2
1943 (January to September) ...	6·03	4·1
Egypt, Western Desert and North Africa		
1941	184·66	4·6
1942	258·61	4·3
1943	238·96	3·7
1944	284·15	7·5
1945	229·02	8·2
Persia and Iraq Force		
1941	819·63	25·3
1942	2,637·62	30·6
1943	3,011·77	29·9
1944	1,631·09	27·0
1945	799·73	17·6

GENERAL MORBIDITY—INDIA, BURMA AND SEAC (EXCLUDING CEYLON)

Malaria, dysentery, diarrhoea, venereal diseases, minor septic diseases, common cold and skin diseases stand out prominently as the principal causes of morbidity. During 1943 and 1944, injuries due to enemy action also increased. The above mentioned diseases accounted for 70 per cent. of all admissions in 1942, 66 per cent. in 1943, 59 per cent. in 1944 and about 48 per cent. in 1945. The most important single cause of morbidity was malaria (418 per 1,000 in 1942, and 479 in 1943).

TABLE IV

Admissions into hospitals for Indian troops on Indo-Burma front, Burma and SEAC (excluding Ceylon).

Diseases	1942		1943		1944		1945 January to September	
	Actual	Rate per 1,000	Actual	Rate per 1,000	Actual	Rate per 1,000	Actual	Rate per 1,000
Common cold	2,091	14·56	12,901	34·37	13,617	31·91	6,687	16·43
Dysentery	7,097	49·42	12,729	33·91	15,785	37·00	5,028	12·35
Malaria	60,072	418·33	179,774	478·90	134,688	315·68	18,577	45·63
Minor septic diseases ...	4,044	28·16	13,199	35·16	11,819	27·70	7,639	18·76
Tuberculosis	303	2·11	573	1·53	506	1·19	507	1·24
Venereal diseases	6,426	44·75	26,831	71·47	15,647	36·67	12,952	31·81
Mental diseases	203	1·41	1,164	3·10	1,827	4·28	2,169	5·33
Influenza	1,623	11·30	1,015	2·70	267	0·63	162	0·40
Diarrhoea	3,629	25·27	10,499	27·97	14,839	34·78	4,950	12·16
Skin diseases	1,721	11·98	9,012	24·01	10,388	24·35	6,359	15·62
Other diseases	34,772	242·14	134,831	359·17	151,037	354·00	63,451	155·86
Injuries (NEA)	5,254	36·59	16,136	42·98	18,494	43·35	15,294	37·57
Total casualties (NEA) ...	127,235	886·04	418,664	1,115·27	388,914	911·54	143,775	353·17
Injuries caused by blast ...	...	...	...	...	134	0·31	38	0·09
Bomb wounds	7	0·05	890	2·37	3,809	8·93	2,764	6·79
Gunshot wounds	575	4·00	1,416	3·77	6,867	16·09	5,279	12·97
Shell wounds	58	0·40	452	1·20	3,845	9·01	2,296	5·64
Total casualties (EA) ...	640	4·46	2,758	7·35	14,655	34·35	10,377	25·49
Admissions all causes ...	127,875	890·50	421,422	1,122·63	403,569	945·88	154,152	378·66

TABLE V

Admissions into hospitals for BORs on Indo-Burma front, Burma and SEAC (excluding Ceylon).

Diseases	1942		1943		1944		1945 January to September	
	Actual	Rate per 1,000	Actual	Rate per 1,000	Actual	Rate per 1,000	Actual	Rate per 1,000
Common cold	525	11·7	1,229	21·3	1,460	18·50	869	12·46
Dysentery	3,946	87·8	7,605	132·0	7,689	97·44	3,392	48·62
Malaria	15,045	334·7	36,201	628·2	32,005	405·58	6,715	96·26
Minor septic diseases ...	2,404	53·5	3,799	65·9	3,841	48·67	2,913	41·76
Tuberculosis	44	1·0	50	0·9	33	0·42	33	0·48
Venereal diseases	3,246	72·2	9,101	157·9	5,463	69·23	3,777	54·14
Mental diseases	115	2·5	349	6·1	859	10·88	1,216	17·43
Influenza	171	3·8	311	5·4	79	1·00	18	0·26
Diarrhoea	1,872	41·7	4,439	77·0	7,198	91·21	1,822	26·12
Skin diseases	1,719	38·2	2,881	50·0	2,851	36·13	2,678	38·39
Other diseases	16,779	373·7	34,646	601·3	43,776	554·75	17,357	248·80
Injuries (NEA)	1,491	33·2	3,712	64·4	4,325	54·81	3,180	45·58
Total casualties (NEA) ...	47,357	1,053·9	104,323	1,810·4	109,579	1,388·62	43,970	630·29
Injuries caused by blast ...	...	...	...	...	65	0·82	22	0·31
Bomb wounds	25	0·5	140	2·4	1,724	21·85	660	9·46
Gunshot wounds	178	3·9	509	8·8	4,325	54·81	2,125	30·46
Shell wounds	6	0·1	156	2·7	1,928	24·43	1,026	14·71
Total casualties (EA) ...	209	4·5	805	13·9	8,042	101·91	3,833	54·94
Admissions all causes ...	47,566	1,058·4	105,128	1,824·3	117,621	1,490·53	47,803	685·24

Malaria : Malaria was the greatest problem in Burma and SEAC. In April 1942, a large railway project at Rangapahar was rendered ineffective as about 90 per cent. of the labour was affected by malaria. In three months, October to December 1942, 18,000 cases were evacuated from the Eastern Army alone. It is estimated that the daily average of malaria cases in 1943 and 1944, was 5,560 and 3,606 respectively. When the engagements took place in the malarial season the formations literally melted away. The 6th Indian Infantry Brigade, for example, in the Mayu Range from March to May 1943, suffered 69·6 per cent. casualties. In 1944, the total number of admissions to the hospitals in the Fourteenth Army corresponded approximately to one division a month, while the number of constantly sick was about half a division. A large number of these cases suffered from malaria. The highest incidence of malaria in the Indian troops in Burma and SEAC (excluding Ceylon), Ceylon, Sudan and Eritrea, Persia and Iraq and Egypt, Western Desert and North Africa was 478·90 (1943), 193·63 (1942), 111·33 (1942), 117·45 (1941) and 38·21 (1943) per 1,000 respectively. The high relapse rate of the benign tertian (BT) and the varied severe manifestations of the malignant tertian (MT) gave rise to serious anxiety.

During the early part of the war, the treatment of malaria was on the lines recommended by the League of Nations. In 1942, the system of treating malaria by giving quinine for two days, mepacrine for five days, rest for two days and pamaquin for five days was introduced. The work of Shannon as well as the experience in other theatres of war suggested that the treatment with mepacrine alone was satisfactory if a sufficient dosage was given at the initial stage to ensure a high mepacrine blood level rapidly and small maintenance dosage thereafter. Controlled and successful trials of this treatment resulted in the introduction of the all-mepacrine treatment. In areas where suppressive mepacrine discipline was not enforced all the patients recovering from malaria were given a maintenance dose (0·1 g. daily for 42 days) after discharge from the hospital. Experience had shown that the tendency to primary relapse in BT malaria was noticeable in the first six weeks after recovery and the second relapse about six months after initial attack. The six weeks maintenance course was designed to cover this initial tendency to relapse and also to cure all cases of MT infection. At the time, the stock position of mepacrine did not permit a longer maintenance period. The aim up to 1945, however, was that when sufficient mepacrine was available all cases which had relapsed twice should be placed on continuous suppressive therapy, no matter in what part of the country they were located. A trial of combined treatment with quinine and pamaquin, ten grains each, thrice daily for ten days, given concurrently, was instituted for BT relapse patients. It was noticed that 34 per cent. of the 384 cases so treated relapsed within three months. These results and the danger of pamaquin haemoglobinuria indicated that it was not justifiable to continue this treatment. The all-mepacrine treatment was found relatively the best available. The problem of BT malaria relapses still remained unsolved, although much was learnt about the treatment of

MT malaria. The necessity for immediate diagnosis and treatment of cases of cerebral malaria had to be frequently emphasised. Ransome, Gupta and Paterson introduced the routine management of cerebral cases in Fowler's position combined with drip-hydration and nutrition by the Ryle's tube. The incidence of black-water fever on the Indo-Burma front was low being 0·01 per 1,000 from January to September 1945. This was attributed to the use of mepacrine. The aetiology of black-water fever was not clear. It was suggested that the main cause may be renal ischaemia and anoxia.

Dysentery: Next to malaria, diarrhoea and dysenteries were the most common ailments. The highest incidence of dysentery in Indian troops in Burma and SEAC (excluding Ceylon), Ceylon, Sudan and Eritrea, Persia and Iraq and Egypt, Western Desert and North Africa respectively was 49·42 (1942) 24·64 (1944), 24·86 (1942), 29·50 (1941) and 28·77 (1942) per 1,000.

GRAPH 1

INCIDENCE (RATE PER 1,000) OF DYSENTERY AND DIARRHOEA ON INDO-BURMA FRONT FOR ALL FORCES.

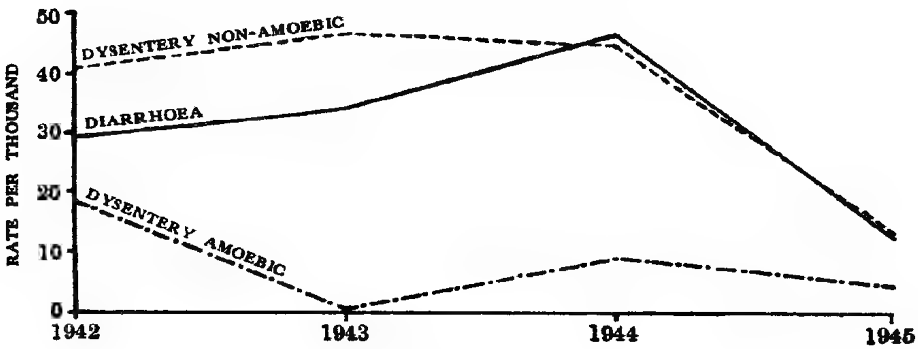


TABLE VI

Incidence (rate per 1,000) of dysentery and diarrhoea among Indian and British troops in the India Command.

Diseases	1939	1940	1941	1942	1943	1944	1945
Diarrhoea ...	9·39	13·57	27·58	37·65	28·57	25·22	21·36
Dysentery clinical ...	3·65	4·92	7·80	11·36	10·23	7·98	5·42
Dysentery protozoal ...	1·14	1·29	1·52	1·85	2·58	4·94	4·03
Dysentery bacillary ...	12·89	14·90	10·51	8·38	6·70	9·09	11·22
Dysentery bacillary exudate ...	2·30	3·17	3·19	2·61	1·96	2·63	3·25

Sulphaguanidine was not available for general treatment of bacillary dysentery until 1943 but supplies progressively increased. The policy was to allow full supplies for forward areas and to retain the balance for use in the base and garrison hospitals. All cases in forward areas were thus ensured treatment with sulphaguanidine. Some cases were also treated with other sulpha drugs, especially sulphathiazole. Succinyl sulphathiazole was available in small quantities only and its use was reserved for surgical cases involving intestinal operations. With the introduction of sulpha drugs bacillary dysentery ceased to cause anxiety. The treatment of amoebic dysentery, however, continued to be difficult. Until 1945, anti-amoebic drugs were in short supply. It was, therefore, a case of using whatever was available with the result that cases of amoebic dysentery were treated with 12 injections of emetine hydrochloride followed by arsenical preparations, if available, otherwise, additional six emetine injections were given. This treatment was repeated in relapse cases and it happened that some of the relapsed cases received upward of 100 injections of emetine. The relapse rate unfortunately was high and a large number of cases of chronic amoebiasis amongst the British troops had to be evacuated to the hospitals in the United Kingdom. It was alleged that these cases were not treated satisfactorily. While admitting the justification of the criticism it was urged, in extenuation, that India at the time could give no other treatment as drugs like chiniofonum, emetine bismuth iodide (EBI) and diodoquin were not available. As the supply situation improved a standard treatment was introduced in 1944. The need for a fresh outlook was, however, obvious and special emphasis had to be laid on the fact that the initial attack must be taken seriously and treated earnestly as soon as possible. Greater effort for early diagnosis and a complete clearance examination repeated three weeks after the discharge of the patient from the hospital was considered essential at the termination of the treatment. The value of sigmoidoscopy was stressed, and to ensure its routine practice in all hospitals, sanction was given for the provision of a sigmoidoscope in each hospital of 300 beds and over. Hospitals of over 1,200 beds were provided with two sigmoidoscopes. The results of the standard treatment were gratifying and this was attributed to the establishment of a well-regulated system of therapy and follow up. The course of treatment outlined was a compromise between the patients' requirements and the drugs available and it consisted of six injections of emetine and chiniofonum retention enema. The short supply of EBI necessitated its relegation to the background.

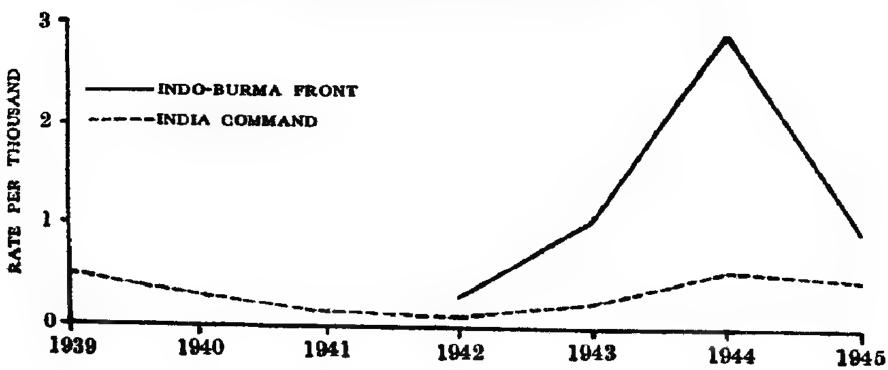
The search for effective amoebicides, however, continued unabated. Two research teams, at Ranchi and Poona, were set up to test the drugs and to report on their efficacy. By the middle of 1945, liberal supplies of EBI became available and encouraging reports on the value of diodoquin were received. It was also noticed that amoebic ulcers were complicated by an advanced degree of secondary infection which indicated the necessity of previous treatment of chronic amoebic dysentery cases with sulphasuxidine and later with penicillin. The standard treatment was modified accordingly. The new treatment recognised EBI as the drug of prominent value. Emetine injections

twice or thrice were permissible only for relieving initial acute symptoms. The EBI therapy was supplemented by the administration of oral diodoquin or enemata of chiniofonum and the treatment was completed with the administration of arsenical preparation for a short period. Emphasis was maintained on the importance of early examination and treatment, and sigmoidoscopy on its termination.

Scrub Typhus: The concentration of troops in Assam and the campaign in Kabaw Valley and other mite-infested regions brought into prominence the menace of scrub typhus. Between July 1943 and October 1944, nearly 3,000 cases were evacuated from the Burma front, with a mortality of about 10 per cent. In the impending campaigns troops in larger numbers were to be employed and they were unduly scared by the risk due to ignorance about the role of mites in the spread of scrub typhus. In view of all these considerations research organisations were set up to study the problem. The GHQ Field Typhus Research Team, Medical Research Council (MRC) Typhus Team, the USA Typhus Commission and others investigated the problem. *Trombicula deliensis* was established as the vector in these regions. Several strains of *Rickettsia tsutsugamushi* were also isolated. The extreme prostration in most cases, the rash, the frequency of respiratory complications, the association of malaria, the temporary nature of cardiac affection were some of the important features observed. It was also noticed that it was dangerous to move the patients after the fifth day of the disease. In the absence of any specific treatment (before the introduction of chloromycetin) the patients were treated on general lines such as nursing, fluid and salt balance and adequate nutrition. If cyanosis set in, it was found necessary to give oxygen.

GRAPH 2

INCIDENCE (RATE PER 1,000) OF TYPHUS FEVER FOR ALL FORCES ON INDO-BURMA FRONT AND INDIA COMMAND.



Infective Hepatitis: The incidence of infective hepatitis in India and Burma did not assume the same proportions as in the Middle East. The features of the disease, however, were identical with those observed there.

Its incidence was low among the Indian troops which might be due to the fact that the Indian troops had acquired an immunity in early life. Mortality among the Indian troops was higher than the British due to their lower protein intake and poor nutritional reserve. The post-arsenical jaundice, common both among the Indian and British troops, was found to be due to the transmission of the causative agent through the syringes used for injections. It appeared to be of greater severity than true infective hepatitis, showed longer duration and greater liability to haemorrhages and was associated with higher mortality.

Anaemia and Malnutrition: In Assam and Burma, a malnutrition anaemia syndrome appeared in some cases and these responded to the improvements in rations, mainly fresh protective food and proteins of high biological value. A triad of symptoms, diarrhoea, anaemia and loss of weight, was the outstanding features of some of them. The loss of weight was so great in a large number of such cases that they were reduced to a bag of bones. These cases were labelled as suffering from marasmus syndrome. Recovery was slow and most of them required more than four months of treatment in a hospital. Vitamins, iron, liver extracts, yeast, high protein diet and transfusion (whole blood and red cell concentrates), were all advocated as cures. Anaemia treatment centres were opened to treat and study such cases in the Central Command and the Southern Army in 1943. A marasmus investigating team was raised in 1945 to work in No. 145 IBGH(IT). The marasmus syndrome was limited to the Indian troops only. The British troops, on the other hand, suffered from sprue, or sprue-like syndromes. Over 1,000 cases were evacuated as invalids to the United Kingdom during 1943-45. It was suggested that the condition was caused by a defective biosynthesis resulting from the changes in intestinal flora and the breakdown of enzymic system related to phosphorylation, which in turn was ascribed to the deficient co-enzyme embodying known and unknown members of vitamin B complex. After the cessation of hostilities a large number of cases of multiple deficiencies, nutritional oedema, spastic syndromes, burning feet, muco-cutaneous lesions, etc., were observed in the recovered allied prisoners of war and internees (RAPWI).

Heat Effects: The loss of water and salts caused by high temperature and humid climate led to a number of cases of heat effects and dehydration.

Skin Diseases: Detailed figures for skin diseases are not available for the Indo-Burma front. It is, however, interesting to observe that minor septic diseases ranked fourth amongst the sick casualties, on this front. Excessive perspiration, septic abrasions, insect bites and fungus infections of the groins and feet accounted for most of the skin diseases. The details of skin diseases among IORs and BORs of the Army in India are shown in Table VII.

Such wide prevalence of skin diseases was greater than the official anticipation. A pre-war establishment of seven dermatologists treated not only skin but also venereal diseases ; they were equipped for combating the latter but not the former. As the army expanded, more

TABLE VII

Incidence (rate per 1,000) of skin diseases among VCOs, IORs and BORs in the India command.

Diseases	1939		1940		1941		1942		1943		1944		1945	
	VCOs and IORs	BORs	VCOs and IORs	BORs	VCOs and IORs	BORs	VCOs and IORs	BORs	VCOs and IORs	BORs	VCOs and IORs	BORs	VCOs and IORs	BORs
Acne	0·1	0·5	0·1	0·5	0·1	0·3	0·1	0·6	0·1	0·5	0·2	1·7	0·2	2·1
Dermatitis	5·1	5·4	4·7	2·4	4·5	6·4	6·6	10·9	7·6	6·5	9·5	8·5	9·5	9·8
Eczema	2·4	2·0	3·2	6·7	3·3	2·5	3·2	3·0	3·6	2·2	4·1	2·8	3·9	2·9
Herpes zoster	0·6	0·8	0·6	0·6	0·6	0·4	0·6	0·7	0·8	0·7	1·1	1·3	1·0	1·5
Impetigo	1·2	11·4	0·9	11·7	1·2	7·9	1·4	14·0	1·9	8·7	2·5	9·7	2·9	12·5
Ingrowing toe-nail ...	0·0	3·4	0·0	4·0	0·0	3·8	0·1	3·2	0·1	2·3	0·1	2·5	0·2	3·1
Onychia	0·1	0·3	0·0	0·2	0·0	0·1	0·1	0·0	0·1	0·3	0·0	0·1	0·0	0·3
Prickly heat	0·1	0·9	0·0	0·5	0·1	0·8	0·1	1·1	0·1	0·7	0·2	1·9	0·3	5·0
Psoriasis	0·3	0·8	0·2	1·2	0·3	0·6	0·2	0·7	0·3	0·6	0·3	0·8	0·4	1·1
Sycosis (folliculitis) ...	0·2	1·1	0·4	0·7	0·3	0·5	0·1	0·6	0·3	0·4	0·8	0·9	0·7	2·1
Ringworm (tinea) ...	3·8	9·5	3·4	9·9	2·8	8·6	3·3	7·5	4·1	3·9	7·2	8·9	5·7	10·8
Urticaria	0·9	0·9	0·7	1·0	1·1	1·0	1·0	1·8	0·9	1·3	1·1	2·8	1·4	2·1
Wart	0·1	1·1	0·1	2·4	0·2	1·1	0·2	1·4	0·3	0·9	0·4	0·9	0·7	1·9
Whitlow	1·6	0·6	0·7	0·9	0·7	0·8	0·7	1·5	0·8	0·7	1·2	1·7	1·6	1·6
Other skin diseases ...	0·7	3·2	0·7	2·0	0·7	3·5	1·3	8·5	1·8	7·7	3·3	5·8	3·8	9·2

and more troops were affected by the skin diseases, (including scabies, classified as a non-dermatological disorder) and venereal diseases ; but the establishment continued to be unaltered until early in 1943, when an adviser was appointed to help in what had then become an administrative problem. Later in 1943, dermatology and venereology were separated, each speciality having an adviser, and the dermatological problem then was to find or train specialists and nursing staff. Technical instructions were issued to acquaint regimental medical officers (RMOs) and others with the rudiments of dermatology, including treatment for the commonest affections in the hope that early recognition and adequate simple therapeutic measures would diminish the pressure on hospital beds for the sick, for in most theatres of war ten per cent. of the beds had to be allocated for skin diseases, including scabies. The great increase in dermatological work was not attributable to campaigning in unhealthy terrain—a similar increase occurred in Europe in World War I. Most cases of inflammation of areolar tissue admitted to surgical wards began with some lesion of the skin that was not skilfully treated in the early stage. Infection of the skin was the usual sequel to some defect in skin hygiene, the prevalence of scabies being outstanding. Prickly heat incommoded mainly because the lesions usually turned septic after scratching. Adverse climatic conditions were responsible for the occurrence of jungle sores, prickly heat and wide spread fungus infections.

Venereal Diseases : The problem of venereal diseases remained difficult throughout. These diseases were acquired mostly in the base areas or during leave. The introduction of sulpha drugs and later penicillin considerably reduced the number of 'man days' lost due to gonococcal infection.

TABLE VIII.

Incidence (rate per 1,000) of venereal diseases on Indo-Burma front for all forces (Indian, British, East African and West African).

Diseases	1942	1943	1944	1945 January to September	Remarks
Syphilis ...	9·54	...	...	5·36	Details for 1943 and 1944 are not available.
Gonorrhoea ...	15·23	...	...	10·33	
Soft chancre ...	4·04	...	...	0·12	
Other venereal diseases ...	21·38	...	...	20·44	
Total ...	50·19	81·17	47·43	36·27	

Neurological Diseases : Amongst the neurological diseases, meningitis, acute poliomyelitis, epilepsy, peripheral neuritis, late effects of head injuries, neurological complications of malaria and heat stroke and neuropathies observed in the prisoners of war (POW) were of special interest. Incidence of some of these diseases is shown in Table IX.

TABLE IX.

Incidence (rate per 1,000) of neurological diseases among Indian and British troops in the India Command.

Diseases	1939	1940	1941	1942	1943	1944	1945
Poliomyelitis ...	0·05	0·02	0·03	0·07	0·05	0·09	0·18
Epilepsy ...	0·29	0·85	1·19	1·38	1·23	0·63	0·34
Neuritis ...	0·45	0·35	0·41	0·61	0·67	0·64	0·53
Meningitis ...	0·06	0·06	0·15	0·31	0·28	0·15	0·10

Psychiatric Disorders : Psychiatric disorders presented a major medical problem and it is estimated that from 10 to 15 per cent. of all casualties showed psychiatric symptoms. Arrangements for special treatment had to be made for these casualties. Practically the whole of this work grew up during the war as few facilities existed in the Indian Army in peace time. In pre-war days, patients whose psychiatric disabilities did not clear up with the simplest treatment, were boarded out of the army. Such a method of disposal was, of course, out of the question in war. Advance in psychiatric work took two forms ; the training of psychiatrists and mental nursing orderlies (MNOs) and the provision of special accommodation. An expansion of the establishment of psychiatric specialists from 4 to 86 naturally involved a variety of training schemes. It, however, also meant that, in the course of time, treatment of every type was available. In the forward areas, under the divisional psychiatrists, patients received early treatment ; and about 25 per cent. of these were returned to duty. On the lines of communication and in the base areas the number of beds reserved for the care and treatment of psychiatric patients varied between 3,000 and 4,000. Where possible, out-patient clinics were set up. Accommodation was a serious problem. Specially designed 25-bed wards (capable of expansion) were built as part of many general hospitals in all areas. In addition, there were several bigger centres in Comilla, Calcutta, Ranchi, Moradabad, Poona, Secunderabad and finally a 1,000 bed hospital at Jalahali ' hospital town '.

The types of illness showed certain points of interest. Psychiatric symptoms were common as an accompaniment of malaria and, now and then, of typhus. Amongst the Indian troops conversion symptoms were more frequent than among the British soldiers in whom anxiety states were generally more prominent. Schizoid episodes were often found, and with adequate treatment responded well. The medical regulations laid down that patients with psychotic symptoms must be boarded out from the army. Experience with this short-lived type of schizophrenia, however, was such that the old policy had to be changed.

The training of the Indian MNOs, a new departure, served a valuable purpose during the war. It was anticipated that these MNOs would be welcomed in the civil mental hospitals after the war ; and this in fact did occur.

TABLE X

Incidence (rate per 1,000) of mental disorders among officers (Indian service) VCOs, IORs, officers (British service) and BORs in the India Command.

Mental disorders	1939				1940				1941				1942				1943				1944				1945			
	Officers (IS)	VCOs IORs	Officers (BS)	BORs	Officers (IS)	VCOs IORs	Officers (BS)	BORs	Officers (IS)	VCOs IORs	Officers (BS)	BORs	Officers (IS)	VCOs IORs	Officers (BS)	BORs	Officers (IS)	VCOs IORs	Officers (BS)	BORs	Officers (IS)	VCOs IORs	Officers (BS)	BORs	Officers (IS)	VCOs IORs	Officers (BS)	BORs
Mental deficiency	...	0·01	...	0·2	...	0·02	...	0·03	0·7	0·1	...	0·4	...	0·2	...	0·6	...	0·3	0·1	0·4	0·2	0·6	0·6	0·7	0·2	0·8	0·1	0·6
Psychoneurosis :																												
Hysteria ...	0·9	0·5	0·5	0·9	0·3	1·0	...	0·8	0·7	0·9	0·3	0·7	0·9	1·2	0·5	0·7	0·4	1·7	0·9	0·6	0·5	1·9	1·3	1·9	0·9	2·1	1·2	2·2
Anxiety states ...	1·7	0·3	1·6	0·4	0·8	0·2	1·5	0·5	5·0	0·4	3·1	1·6	5·2	0·5	4·8	2·2	6·0	0·5	5·3	1·9	5·7	0·7	11·8	5·7	9·6	1·1	11·7	7·7
Psychosis :																												
Manic-depression	...	0·1	...	0·1	...	0·1	...	0·2	0·2	0·3	...	0·2	0·3	0·3	0·3	0·2	0·5	0·3	...	0·04	0·2	0·3	0·1	0·1	0·1	0·1	0·2	0·05
Schizophrenia	...	0·1	...	0·3	...	0·2	...	0·3	0·3	0·2	...	0·5	0·1	0·2	0·5	0·5	0·4	0·6	1·1	0·6	0·7	0·8	1·1	0·8	0·6	0·7	0·7	0·9
Other mental disorders ...	2·1	0·3	2·7	1·2	2·6	0·4	2·5	1·2	1·2	0·3	2·2	1·2	0·9	0·6	1·3	1·2	1·2	0·9	3·0	1·1	1·5	1·6	2·8	3·3	1·3	2·0	2·3	1·7
Total ...	4·7	1·3	4·8	3·1	3·7	1·9	4·0	3·0	8·1	2·2	5·6	4·6	7·4	3·0	7·4	5·4	8·5	4·4	10·4	4·6	8·8	5·9	17·7	12·5	12·7	6·8	16·2	13·2

The sickness rate per 1,000 of psychiatric patients on the Indo-Burma front was 1·41 in 1942, 3·10 in 1943, 4·28 in 1944, and 5·33 in 1945. The rise in incidence was due to the altered conditions in which fighting took place. Exhaustion, malaria, dysentery, etc., were generally found in association with psychiatric disabilities. It was rare to find a patient with a clear-cut clinical picture. The absolute morbidity rates for psychosis, psychoneurosis and not yet diagnosed (NYD) mental diseases during 1945 were 0·86, 1·20, and 3·26, respectively, on this front. It often happened—more often than not—that the diagnosis was revised when the patient reached the hospital. Not all the patients were seen in the first instance by a psychiatrist—this was not possible—and so strange terms were often affixed. One 'label' found happily as a rarity, was 'NYD lunatic'.

Psychiatric casualties observed in the India Command among officers, VCOs, IORs and BORs during 1939-45 are shown in Table X.

Other Diseases :—Besides the diseases and disorders mentioned above, reference has also been made in this volume to arsenical encephalopathy, brucellosis, hill diarrhoea, ancylostomiasis, leishmaniasis, leprosy, *Salmonella enteritidis* as cause of enteric fever, tuberculosis, pulmonary eosinophilosis and cholera, on account of some features of special interest. Plague, relapsing fever, yellow fever, filariasis, dengue and sandfly fever did not present any military problem. It may, however, be added that a great deal of work was done on plague in India during the war. It was found that the mortality due to plague could be lowered with the use of sulphathiazole, sulphadiazine (later also streptomycin) specially when given in combination with antiserum. It was also observed that a vaccine of living non-virulent organisms gave better protection than a killed vaccine in experimental animals.

TABLE XI

Incidence (rate per 1,000) of certain diseases among Indian and British troops in the India Command.

Diseases	1939	1940	1941	1942	1943	1944	1945
Sandfly fever	11·75	9·28	13·10	8·90	4·04	3·11	1·53
Tuberculosis	2·01	2·54	2·36	2·68	2·61	2·68	2·63
Dengue ...	3·13	2·10	1·98	3·41	2·63	3·91	2·12
Enteric fever	0·70	0·83	0·65	0·63	0·56	0·68	0·47
Leishmaniasis :							
Kala-azar	0·39	0·23	0·28	0·15	0·15	0·27	0·31
Oriental sore	1·03	0·52	0·44	0·56	0·22	0·12	0·14
Sprue ...	0·09	0·06	0·10	0·08	0·13	0·39	0·30
Filariasis ...	...	0·04	0·12	0·09	0·09	0·10	0·10
Leprosy ...	0·04	0·09	...	...	0·85	1·11	0·65
Relapsing fever	0·03	0·04	0·04	0·06	0·02	0·05	0·10
Cholera ...	0·01	0·01	0·26	0·08	0·18	0·08	0·10
Encephalitis	0·01	0·08	0·01	0·01	0·02	0·04	0·02
Plague ...	...	...	...	...	0·03	0·01	0·02

CEYLON

The pattern of morbidity rates in Ceylon was almost the same as in Burma, except the extent of sickness in some cases.

EGYPT, WESTERN DESERT AND NORTH AFRICA

With regard to Egypt, Western Desert and North Africa, it will not be quite correct to treat the figures of 1939 and 1940 as representative samples for Indian troops, for they are not complete. Figures for 1941 pertain only to four months of that year, viz., September to December. The major diseases again remained the same as in Burma or Ceylon, with the only difference that their individual rates were very much lower. In Egypt, however, enemy action casualties occupied a very important position during the period of hostilities from 1941 to 1943. Total morbidity rates were of the order of 603·12 per 1,000 in 1941, 582·34 in 1942, 438·33 in 1943, 409·18 in 1944 and 330·34 in 1945. The major diseases constituted about 30 to 35 per cent. of all casualties each year, except in 1944, when the relevant figure was 28 per cent. Non-enemy action casualties accounted for 92 per cent. of all admissions in 1941, 96 per cent. in 1942, 94 per cent. in 1943, 98 per cent. in 1944 and about 100 per cent. in 1945. It will also be noted that malaria was the most important single cause only in 1943 when the rate was 38·21 per 1,000. In other years this position was occupied by either minor septic diseases or venereal diseases.

SUDAN AND ERITREA

During 1940 and 1941, which were the years of maximum concentration of troops in these areas, the major causes of morbidity among Indian troops were battle casualties, venereal diseases, dysentery, diarrhoea, minor septic diseases and malaria. Enemy action was responsible for about one-fourth of all casualties in 1941. Venereal diseases, dysentery, diarrhoea and minor septic diseases each caused higher admissions than malaria in that year. During these two years, the overall rate of morbidity was comparatively very low. It was only 59·29 per 1,000 in 1940 (September to December) and 390·76 per 1,000 in 1941.

PERSIA AND IRAQ

It seems remarkable that the major diseases should follow almost a fixed morbidity pattern in this area also, viz., malaria, venereal diseases, minor septic diseases, common cold, dysentery and diarrhoea. This morbidity pattern was disturbed in 1945, when venereal diseases were the cause of maximum admissions. Also the places of dysentery and diarrhoea, though contiguous, remained a little indefinite from year to year. Thus malaria remained the most important single cause of hospital admissions almost throughout. Overall morbidity rates

TABLE XII

Admissions into hospitals for Indian troops in Ceylon.

Diseases	1942		1943		1944		1945	
	Actual	Rate per 1,000	Actual	Rate per 1,000	Actual	Rate per 1,000	Actual	Rate per 1,000
Common cold	268	17·64	207	8·93	443	25·69	120	8·36
Dysentery	290	19·09	523	22·57	425	24·64	269	18·75
Malaria	2,941	193·63	4,354	187·89	2,661	154·30	925	64·48
Minor septic diseases ...	1,084	71·37	1,022	44·10	375	21·74	351	24·47
Tuberculosis	53	3·49	230	9·92	29	1·68	17	1·18
Venereal diseases	703	46·28	1,025	44·23	680	39·43	528	36·81
Mental diseases	40	2·63	68	2·93	78	4·52	84	5·86
Influenza	30	1·97	11	0·47	3	0·17	5	0·35
Diarrhoea	473	31·14	511	22·05	239	13·86	163	11·36
Skin diseases	...	...	...	...	362	20·99	310	21·61
Injuries (NEA)	985	64·85	1,088	46·95	886	51·38	615	42·87
Other diseases	7,229	475·94	8,283	357·44	5,228	303·16	3,877	270·27
Total casualties (NEA) ...	14,096	928·04	17,322	747·51	11,409	661·59	7,264	506·38
Bomb wounds	1	0·07	...	...	...	...	...	...
Gunshot wounds	9	0·59	18	0·78	6	0·35	1	0·07
Shell wounds	...	...	1	0·04	...	...	...	...
Total casualties (EA) ...	10	0·66	19	0·82	6	0·35	1	0·07
Admissions all causes ...	14,106	928·70	17,341	748·33	11,415	661·93	7,265	506·45

TABLE XIII

Admissions into hospitals for Indian troops in Egypt, Western Desert and North Africa.

Diseases	1939		1940		1941 (September to December)		1942		1943		1944		1945	
	Actual	Rate per 1,000	Actual	Rate per 1,000	Actual	Rate per 1,000	Actual	Rate per 1,000	Actual	Rate per 1,000	Actual	Rate per 1,000	Actual	Rate per 1,000
Common cold ...	48	7·42	168	15·30	319	5·68	1,972	24·01	1,097	12·48	576	11·86	222	6·64
Dysentery ...	150	23·18	315	28·68	649	11·57	2,363	28·77	864	9·83	493	10·15	204	6·10
Malaria ...	134	20·70	239	21·76	422	7·52	2,187	26·62	3,357	38·21	1,230	25 33	359	10·74
Minor septic diseases ...	144	22·25	216	19·67	663	11·81	2,682	32·65	2,288	26·04	1,353	27·87	621	18·57
Tuberculosis ...	2	0·31	18	1·64	26	0·46	146	1·78	201	2·29	90	1·85	67	2·00
Venereal diseases ...	179	27·66	433	39·42	583	10 39	2,021	24·60	969	11·03	825	16·99	1,096	32·78
Mental diseases ...	3	0·46	23	2·09	52	0·93	333	4·05	342	3·89	237	4·88	154	4·60
Influenza ...	...	...	6	0.55	2	0.04	103	1·25	17	0·19	26	0·53	8	0·24
Diarrhoea ...	111	17·15	105	9·56	170	3·03	1,839	22·39	969	11·03	328	6·75	206	6·16
Skin diseases ...	...	...	...	...	...	...	...	...	...	...	...	...	692	20·69
Injuries (NEA) ...	271	41·87	497	45·25	1,011	18·02	4,859	59·15	5,014	57·06	2,330	47·99	1,391	41·60
Other diseases ...	1,075	166.10	3,405	310·03	6,444	114·84	27,279	332·08	21,277	242·15	11,915	245·41	6,003	179·53
Total casualties (NEA) ...	2,117	327·10	5,425	493·95	10,341	184·29	45,784	557·36	36,395	414·21	19,403	399·62	11,023	329·65
Bomb wounds ...	...	...	...	...	162	2·89	289	3·52	214	2 43	47	0·97	4	0·12
Gunshot wounds ...	...	...	...	...	677	12 06	1,198	14·58	953	10·85	172	3·54	13	0·39
Shell wounds ...	...	...	...	...	101	1·80	564	6·87	952	10·83	245	5·05	6	0·18
Total casualties (EA) ...	...	...	...	...	940	16·75	2,051	24·97	2,119	24·12	464	9·56	23	0·69
Admission all causes ...	2,117	327·10	5,425	493·95	11,281	201·04	47,835	582·34	38,514	438·33	19,867	409·18	11,046	330·34

TABLE XIV

Admissions into hospitals for Indian troops in Sudan and Eritrea.

Diseases	1940 (Sept. to Dec.)		1941		1942		1943 (Jan. to Sept.)	
	Actual	Rate per 1,000	Actual	Rate per 1,000	Actual	Rate per 1,000	Actual	Rate per 1,000
Common cold	48	2·57	158	7·67	94	14·51	33	17·61
Dysentery	70	3·75	383	18·60	161	24·86	10	5·34
Malaria	223	11·94	271	13·16	721	111·33	12	6·40
Minor septic diseases ...	64	3·43	294	14·28	133	20·54	28	14·94
Tuberculosis	5	0·27	21	1·02	7	1·08	2	1·07
Venereal diseases	153	8·19	737	35·80	578	89·25	96	51·23
Mental diseases	3	0·16	26	1·26	42	6·49	4	2·13
Influenza	3	0·16	5	0·24	...	...	...	...
Diarrhoea	42	2·25	321	15·59	77	11·89	7	3.74
Injuries (NEA)	101	5·41	487	23·65	393	60·69	49	26·15
Other diseases	379	20·31	3,312	160·88	2,161	333·69	279	148·87
Total casualties (NEA) ...	1,091	58·43	6,015	292·15	4,367	674·34	520	277·48
Bomb wounds	3	0·16	424	20·59	4	0·62	...	...
Gunshot wounds	12	0·64	1,282	62·27	8	1·23	...	...
Shell wounds	1	0·06	324	15·74	...	...	...	...
Total casualties (EA) ...	16	0·86	2,030	98·60	12	1·85	...	...
Admissions all causes ...	1,107	59·29	8,045	390·76	4,379	676·19	520	277·48

TABLE XV

Admissions into hospitals for Indian troops in Persia and Iraq Force.

Diseases	1941 Actual	1941 Rate per 1,000	1942 Actual	1942 Rate per 1,000	1943 Actual	1943 Rate per 1,000	1944 Actual	1944 Rate per 1,000	1945 Actual	1945 Rate per 1,000
Common cold ...	1,698	38·51	3,444	28·71	3,606	26·11	1,329	15·62	586	9·75
Dysentery ...	1,301	29·50	2,219	18·50	2,111	15·28	1,689	19·85	644	10·72
Malaria ...	5,179	117·45	10,621	88·55	14,017	101·48	4,352	51·15	1,596	26·56
Minor septic diseases	1,721	39·03	3,514	29·30	5,304	38·40	2,236	26·28	1,827	30·40
Tuberculosis ...	90	2·04	236	1·97	301	2·18	217	2·55	87	1·45
Venereal diseases	3,124	70·85	7,191	59·95	6,188	44·80	3,213	37·76	2,381	39·62
Mental diseases ...	149	3·38	464	3·87	472	3·42	298	3·50	150	2·50
Influenza ...	198	4·49	22	0·18	20	0·14	40	0·47	88	1·46
Diarrhoea ...	828	18·78	2,335	19·47	2,403	17·40	780	9·17	371	6·17
Skin diseases ...	...	...	...	...	...	...	261	3·07	392	6·52
Injuries (NEA) ...	2,319	52·59	5,064	42·22	6,270	45·39	3,396	39·91	2,074	34·51
Other diseases ...	15,963	362·01	38,262	319·01	41,886	303·24	19,630	230·70	11,237	187·00
Total casualties (NEA) ...	32,570	738·63	73,372	611·74	82,578	597·84	37,441	440·03	21,433	356·68
Injuries caused by blast ...	...	...	...	...	...	...	...	...	4	0·07
Bomb wounds ...	...	...	3	0·02	...	...	...	...	...	...
Gunshot wounds	164	3·72	74	0·62	128	0·93	63	0·74	44	0·73
Shell wounds ...	21	0·47	2	0·02	7	0·05	...	...	...	...
Total casualties (EA)	185	4·19	79	0·66	135	0·98	63	0·74	48	0·80
Admissions all causes ...	32,755	742·82	73,451	612·40	82,713	598·82	37,504	440·77	21,481	357·47

Note :-1941 figures are for ten months. Figures for April and May are not available.

TABLE XVI

Admissions into hospitals for BORs in Persia and Iraq Force.

Diseases	1941 (June to Dec.)		1942		1943		1944		1945	
	Actual	Rate per 1,000	Actual	Rate per 1,000	Actual	Rate per 1,000	Actual	Rate per 1,000	Actual	Rate per 1,000
Common cold	100	9·04	341	9·37	465	10·05	155	10·15	60	6·13
Dysentery	548	49·55	2,078	57·10	1,307	28·24	973	63·70	503	51·38
Malaria	968	87·53	2,617	71·91	2,789	60·27	608	39·80	200	20·43
Minor septic diseases ...	798	72·16	1,786	49·08	2,183	47·17	548	35·87	403	41·17
Tuberculosis	12	1·08	60	1·65	44	0·95	27	1·77	16	1·63
Venereal diseases	872	78·85	2,733	75·10	1,676	36·22	737	48·25	677	69·16
Mental diseases	24	2·17	176	4·84	227	4·90	108	7·07	93	9·50
Influenza	64	5·79	29	0·80	56	1·21	15	0·98	2	0·20
Diarrhoea	489	44·22	2,396	65·84	2,006	43·35	513	33·58	214	21·86
Skin diseases	...	...	...	...	...	...	349	22·85	327	33·40
Other diseases	5,818	526·09	22,021	605·11	21,971	474·77	5,657	370·35	3,139	320·68
Injuries (NEA)	419	37·89	1,864	51·22	2,251	48·64	685	44·84	487	49·75
Total casualties (NEA) ...	10,112	914·37	36,101	992·02	34,975	755·77	10,375	679·21	6,121	625·29
Gunshot wounds	33	2·98	25	0·69	41	0·89	8	0·52	4	0·41
Shell wounds	18	1.63	...	...	2	0·04	...	...	...	...
Total casualties (EA) ...	51	4·61	25	0·69	43	0·93	8	0·52	4	0·41
Admissions all causes ...	10,163	918·98	36,126	992·71	35,018	756·70	10,383	679·73	6,125	625·70

continually fell over the period from 742·82 per 1,000 in 1941, to 357·47 per 1,000 in 1945. During the same period malaria rate was reduced from 117·45 to 26·56 per 1,000. Battle casualties, which were 4·19 per 1,000 in 1941, the year of maximum engagements in this area, were reduced to about 1 per 1,000 for each of the later years. It will be apparent that sick casualties were responsible for the greater part of the overall rate each year. The above mentioned major diseases fluctuated between ratios of 38 per cent. (in 1945) and 46 per cent. (in 1941), of all admissions. The overall morbidity rates of the BORs were consistently higher than those of the VCOs and IORs. The incidence rates for BORs in respect of venereal diseases, minor septic diseases, dysentery and diarrhoea were also higher than IORs. They were, however, lower for malaria and common cold.

ADEN AND SCOTRA

The important causes of admission to hospitals in Aden and Scotra were malaria, dysentery, venereal diseases, minor septic diseases and common cold.

INVALIDMENT

Of the various individual causes of invalidment, tuberculosis occupies a high position. Its rate was never less than 10 per 10,000 and shot up to as high as 17·38 per 10,000 in 1943. It was observed in 1945, that the relaxation of the standards of medical examination of recruits allowed enrolment of many individuals suffering from diseases and defects which often, after a comparatively short period of service, proved to be a cause of invalidment. A large number of recruits were invalided with less than four months service from such diseases as advanced pulmonary tuberculosis, partial blindness, deafness and deformities of limbs. Figures in Table XVII clearly bear out the above statement wherein invalidments due to tuberculosis, mental diseases, respiratory diseases, diseases of bones, joints and muscles, nervous diseases and ear and nose diseases stood out prominently in each year.

VCOs and IORs were invalided at an increasing rate, from 33·61 in 1939 to 181·84 per 10,000 in 1944. This rate fell slightly to 165·33 per 10,000 in 1945. Till 1943, injuries in action caused invalidments at a rate lower than one per 10,000 but after 1943, their rates were 1·50 in 1944 and 4·04 in 1945. The last mentioned figure seems particularly high in this context, though it is a very low rate on the whole, in that year.

CONSERVATION OF MANPOWER

The functions of the medical services are mainly to keep the troops in fighting-fit condition, and to conserve manpower. The former covers a wide field and includes morale, man-management, discipline (especially hygiene discipline) and the varied aspects of preventive medicine. It was repeatedly observed during the war that the success

TABLE XVII

Invalidment of VCOs and IORs during World War II.

Diseases	1939		1940		1941		1942		1943		1944		1945	
	Actual	Rate per 10,000	Actual	Rate per 10,000	Actual	Rate per 10,000	Actual	Rate per 10,000	Actual	Rate per 10,000	Actual	Rate per 10,000	Actual	Rate per 10,000
Specific diseases due to infection :														
Dysentery	...	...	1	0·04	6	0·12	9	0·13	32	0·27	71	0·49	72	0·45
Malaria	2	0·09	14	0·51	24	0·48	65	0·91	262	2·21	236	1·62	196	1·24
Tuberculosis	225	10·04	399	14·58	632	12·66	1,101	15·41	2,062	17·38	2,235	15·35	1,817	11·48
Venereal diseases	5	0·22	20	0·73	12	0·24	34	0·48	177	1·49	182	1·25	64	0·40
Leprosy	4	0·18	18	0·66	...	...	...	...	681	5·74	948	6·51	579	3·66
Other infection diseases ...	12	0·53	17	0·62	112	2·24	281	3·93	135	1·14	142	0·98	178	1·12
Total diseases due to infection ...	248	11·07	469	17·14	786	15·74	1,490	20·86	3,349	28·23	3,814	26·20	2,906	18·35
Mental diseases	56	2·50	140	5·12	259	5·19	607	8·50	1,978	16·67	3,901	26·80	3,617	22·86
Diseases of the respiratory system	39	1·74	138	5·04	272	5·45	736	10·30	2,058	17·35	3,222	22·13	2,846	17·99
Injuries in action	15	0·67	14	0·51	21	0·42	30	0·42	3	0·02	219	1·50	640	4·04
Injuries (NEA)	111	4·95	261	9·54	295	5·91	550	7·70	1,425	12·02	2,306	15·85	2,961	18·72
Diseases of bones, joints, muscles, fasciae and bursae ...	62	2·77	180	6·58	252	5·05	424	5·94	1,164	9·81	1,861	12·78	1,880	11·88
Diseases of ear and nose ...	11	0·49	61	2·23	95	1·90	164	2·30	692	5·83	1,468	10·08	1,776	11·22
Diseases of the skin	7	0·31	28	1·02	84	1·68	155	2·17	635	5·35	1,362	9·36	2,038	12·88

TABLE XVII—(*contd.*)

Invalidment of VCOs and IORs during World War II.

Diseases	1939		1940		1941		1942		1943		1944		1945	
	Actual	Rate per 10,000	Actual	Rate per 10,000	Actual	Rate per 10,000	Actual	Rate per 10,000	Actual	Rate per 10,000	Actual	Rate per 10,000	Actual	Rate per 10,000
Diseases of the nervous system ...	44	1·96	167	6·10	362	7·25	690	9·66	1,410	11·89	1,251	8·59	818	5·17
Diseases of the digestive system ...	32	1·43	119	4·35	186	3·72	311	4·35	661	5·57	1,183	8·13	1,050	6·64
Diseases of the blood and blood-forming organs ...	8	0·36	36	1·32	65	1·30	193	2·70	805	6·79	1,133	7·78	683	4·32
Diseases of the circulatory system	19	0·85	98	3·58	148	2·96	296	4·14	621	5·23	842	5·78	873	5·52
Diseases due to disorders of nutrition and metabolism ...	11	0·49	11	0·40	28	0·56	41	0·57	77	0·65	105	0·72	101	0·64
All other causes	90	4·02	335	12·24	408	8·17	766	10·72	2,786	23·49	3,805	26·14	3,971	25·10
Total	753	33·61	2,057	75·18	3,261	65·31	6,453	90·34	17,664	148·91	26,472	181·84	26,160	165·33

Rates have been calculated against 10,000 strength instead of against the usual 1,000 strength. Since all cases were invalided in India the absolute rates have been calculated against total strength of troops in India and abroad.

TABLE XVIII

Invalidment of Officers (Indian service) during World War II.

Diseases	1939		1940		1941		1942		1943		1944		1945	
	Actual	Rate Per 10,000	Actual	Rate Per 10,000	Actual	Rate per 10,000	Actual	Rate Per 10,000	Actual	Rate per 10,000	Actual	Rate per 10,000	Actual	Rate per 10,000
Specific diseases due to infection :														
Dysentery	...	...	...	...	1	0·85	...	...	2	0·70	...	...	4	1·10
Malaria	...	...	...	...	2	1·70	...	...	2	0·70	...	...	2	0·55
Tuberculosis	1	1·84	3	4·30	3	2·54	10	5·19	1	0·35	...	...	4	1·10
Venereal diseases ...	...	...	...	...	...	...	...	...	...	...	...	...	1	0·28
Other infectious diseases ...	1	1·84	1	1·43	1	0·85	1	0·52	3	1·05	...	...	5	1·38
Total diseases due to infection	2	3·68	4	5·74	7	5·94	11	5·70	8	2·80	..	...	16	4·40
Mental diseases ...	4	7·37	...	...	1	0·85	6	3·11	5	1·75	2	0·60	33	9·08
Diseases of the respiratory system	1	1·84	...	...	1	0·85	3	1·56	1	0·35	1	0·30	4	1·10
Injuries in action ...	...	...	...	...	...	...	1	0·52	...	...	...	...	...	...
Injuries (NEA) ...	3	5·53	...	...	1	0·85	1	0·52	...	...	1	0·30	...	...
Diseases of bones, joints, muscles, fasciae and bursae	1	1·84	...	...	...	...	2	1·04	1	0·35	1	0·30	3	0·83
Diseases of ear and nose ...	...	...	...	...	...	...	...	...	1	0·35	...	...	5	1·38
Diseases of the skin ...	1	1·84	...	...	...	...	...	...	2	0·70	3	0·89	2	0·55
Diseases of the nervous system	2	3·68	1	1·43	...	...	3	1·56	1	0·35	...	...	5	1·38
Diseases of the digestive system	2	3·68	1	1·43	3	2·54	3	1·56	11	3·85	3	0·89	4	1·10
Diseases of the blood and blood-forming organs ...	...	...	...	...	...	...	...	...	...	...	1	0·30	2	0·55
Diseases of the circulatory system	2	3·68	1	1·43	...	...	4	2·07	2	0·70	6	1·79	15	4·13
Diseases due to disorders of nutrition and metabolism	1	1·84	...	...	...	...	...	...	...	...	1	0·30	2	0·55
All other causes ...	1	1·84	2	2·87	...	...	1	0·52	1	0·35	4	1·19	9	2·48
Total	20	36·85	9	12·91	13	11·03	35	18·15	33	11·54	23	6·85	100	27·51

Rates have been calculated against 10,000 strength instead of against the usual 1,000. Since all cases were invalided in India the absolute rates have been calculated against total strength of troops in India and abroad.

depended a great deal on the medical outlook of the regimental commander and the initiative and drive of the regimental medical officer. The conservation of manpower can be accomplished by the provision of best possible medical aid, rapid diagnosis and treatment, and deployment of medical units in such a way that no casualty is allowed to be evacuated further to the rear than necessary. Technical advances and research considerably aided the medical services during the war in rendering relief to the casualties. A large number of nurses, specialists, advisers and consultants, trained in various specialities, technicians and specialists units were provided.

The air evacuation of casualties, previously resorted to only in cases of grave emergency, was gradually accepted as the normal means of evacuation. In the South East Asia covering great distances with poor communications, evacuation by transport planes (Dakotas) from the casualty clearing station (CCS) level to the advanced base was for the most part regular and adequate. It was not uncommon to have cases back at Comilla within 36 to 48 hours of the wound being inflicted. Forward to the CCS, the employment of light aircraft helped the rapid transport of the wounded virtually from the firing line to the CCS.

The treatment in the forward area was provided in field ambulances, MFTUs, CCSs and the mobile surgical units. The policy of forming corps medical centres was also evolved. In general the idea was for two CCSs, two MFTUs and ancillary units to be allotted to each corps and the remaining CCSs and MFTUs being held by the army. Casualties were treated as far as possible in the corps area. All casualties likely to be fit within two months were kept in the army area. A number of base hospitals were grouped in Eastern Bengal.

The mobile surgical units functioned best when attached to a CCS, but they were frequently attached to the main dressing station (MDS) of a field ambulance, close to the light air head. Such a combination of mobile surgical unit and MDS was usually regarded as an advanced surgical centre. The MFTU was originally evolved with the object of holding and treating malaria cases as far forward as possible and returning them quickly to their units, thus preventing the streaming up of the lines of communication and choking the advanced base hospitals. The title of the unit later became a misnomer as all types of medical sick including skin and venereal disease cases were admitted and treated in these units. The number of medical cases admitted to CCSs and MFTUs varied greatly. At peak period, one MFTU held 853 medical cases and one CCS 655 cases. This was, however, exceptional and an average of 200 medical cases, with a peak of 400 to 500, was usual in MFTUs.

The field ambulance on a holding policy of seven days was able to cure one-third to one-half of all the sick. The proportion of medical cases returned to duty from CCSs and MFTUs varied with operational and other circumstances, but was generally in the neighbourhood of 75 per cent.

According to the report *The Utilisation of Hospitals and Manpower* by the Operational Research Group India, by January 1945, the evacuations to India in all conditions other than malaria were 6 per cent. of admissions in the case of officers and BORs and 10 per cent. in the case of IORs. In the case of malaria casualties, only 4 per cent. of IORs admitted were evacuated and no officer or BOR suffering from malaria was evacuated to India.

NURSING OFFICERS

Throughout the war the nursing sisters were regarded as shock troops. In the eastern theatre they were sent wherever the work was heaviest, sometimes even to the MDS of a field ambulance to help mobile surgical units working in the bridgeheads, but normally to MFTUs, and CCSs working under heavy strain. It was the accepted practice in all the units to form a special ward, in which all dangerously ill patients irrespective of rank and race were treated and nursed. It was only by such an arrangement that the fullest use of the very limited nursing personnel could be made. It is a tribute to the magnificent spirit of these nursing officers that in spite of the excessive work, under conditions of great discomfort and danger, their constant plea was to be sent forwards.

CONSULTANTS, ADVISERS AND SPECIALISTS

At the outbreak of the war, army employed 87 specialists only and there were no consultants and advisers. There were eight specialists in medicine, seven in dermatology (including venereology), four in psychiatry, four in anaesthetics, ten in gynaecology and midwifery, ten in radiology, twenty in surgery, eight in ophthalmology, four in oto-rhino-laryngology, and twelve in pathology. By the beginning of 1945 their number had increased to 1,576 including 259 physicians, 261 surgeons, 40 dermatologists, 86 psychiatrists, 194 anaesthetists, 15 gynaecologists, 165 radiologists, 43 otologists, 164 pathologists, 101 hygienists, 78 venereologists, 59 malariologists, and 2 neurologists. The number of specialists available, however, did not keep pace with the demand as will be evident from Table XIX.

Officer-in-Charge Medical Divisions : It was not until the end of 1940, when the war establishments of general hospitals were revised, that provision was made for the appointment of officer-in-charge medical and surgical division in the rank of major. On 19 December 1942, it was decided that in all general hospitals with 1,000 beds or over the officer-in-charge division would hold the rank of lieut.-colonel. In July 1943, provision was also made for these appointments with ranks of major and lieut.-colonel in garrison hospitals with bed strengths of 600 or over and 1,000 or over, respectively. In the beginning, these appointments were made both by the General Headquarters (GHQ) India and officer commanding the unit. On 10 August 1942, it was decided that these appointments would be made by the GHQ alone.

TABLE XIX

Specialist position—March 1944—India and SEAC(a).

Specialists	Staff	British United Kingdom Units	War units			Peace units			Total	Grand total		
			Hospital	Other	Total	Hospital	Other	Total		Liabilities	Available	Deficit
Surgeons	3	40	197	68	265	93	...	93	358	401	243	158
Anaesthetists	1	23	97	36	133	62	...	62	195	219	129	90
Physicians	4	24	145	16	161	93	...	93	254	282	155	127
Radiologists	1	12	21	68	89	62	...	62	151	164	126	38
Pathologists	7	9	11	29	40	...	25	25	65	81	81	...
Hygienists	37	6	...	41	41	...	8	8	49	92	72	20
Psychiatrists	1	...	36	(b)	36	34	...	34	70(c)	71	68	3
Ophthalmologists ...	2	8	18	11	29	17	...	17	46(c)	56	46	10
Venereologists	1	...	72	...	72	53	...	53	125	126	72	54
Otologists	1	8	18	11	29	17	...	17	46(c)	55	34	21
Neurologists	2	2	3	...	3	...	...	...	3	7	4	3
Dermatologists	1	...	12	...	12	12	...	12	24(c)	25	21	4
Gynaecologists	...	...	...	...	...	10	...	10	10	10	8	2
Malariologist	28	2	...	102	102	...	1	1	103	133	91	42
Total	89	134(d)	630	382	1,012	453	34	487	1,499	1, 722	1,150	572

(a) To complete 1943 Target only (including balance that were still to be raised).
(b) Some employed here from within the total pool.
(c) Could be employed in war or peace hospitals—have been shown as 50 per cent. in each.
(d) This represents 46·3 per cent. of authorised medical officer appointments in British medical units.

Officers posted to these appointments were normally specialists. In view of the limited number of specialists and urgent operational requirements, it was decided on 18 September 1943, that these appointments as a temporary expedient might be filled by specially selected officers who might be graded specialists or general duty medical officers ; the GHQ continued to be the posting authority.

Graded Specialists: A special class of specialists called graded specialists was introduced on 16 July 1941. As in the case of recognition as specialist, grading of Indian Medical Service (IMS) officers was also done by the Director General, Indian Medical Service (DGIMS) on the recommendation of the Director Medical Services (DMS). The graded specialists were not eligible for the acting rank of major even when holding specialist appointments but were entitled to the specialist pay.

As stated above the demands for medical officers, in general, and specialists, in particular, were far in excess of the existing assets. In June 1941, the DGIMS put forward a proposal to recruit specialists from among the experienced private medical practitioners. Their terms and conditions of recruitment were sanctioned on 2 December 1941. Only a small proportion of vacancies were to be filled by recruitment of civilian specialists but even this number was not forthcoming. Consequently, specialists were demanded from the India Office and the War Office in London, from time to time, to meet the Indian requirements.

The shortage of specialists necessitated the training of graded specialists in the Indian military hospitals. This training was carried out in selected hospitals by experienced officers in charge of the medical divisions and medical specialists. The principal hospitals engaged in this work were the large base and field hospitals located in Poona, Kirkee, Secunderabad, Bangalore, Lucknow, Bareilly, Moradabad, Ranchi, Calcutta and Dacca. Most of the graded physicians who later applied for recognition as medical specialists, were also posted to these hospitals for a period of observation and report before recognition was granted. Thus, a further period of training was given and a fairly uniform standard was maintained. All physicians were also required to attend a transfusion course. Each unit with a physician thus had a trained resuscitation officer. Special courses on the subjects like leprosy, penicillin, etc., were also conducted for the physicians.

The establishment of specialists in medical units was frequently revised. The establishment originally provided was as follows :—

Combined general hospital (CGH) ...	Surgeon Physician Radiologist (when X-ray apparatus was supplied)
CCS	Surgeon
British general hospital (BGH) ...	Surgeon Physician
Indian general hospital (IGH) ...	Surgeon Physician

Field laboratory ... ... Pathologist
Hospital ship ... ... Surgeon
Physician
Radiologist (when X-ray apparatus was supplied)
Mobile X-ray or X-ray unit ... Radiologist

It was gradually increased to the following :—

Units	Surgeons	Anaesthetists	Physicians	Radiologists	Pathologists	Hygienists	Venereologists	Psychiatrists	Dermatologists	Otologists	Ophthalmologists	Malariologists	Gynaecologists	Neurologists
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Divisional field hygiene section	...	...	...	...	...	1	...	...	...	...	...	...	...	...
Field hygiene section ...	...	...	...	...	...	1	...	...	...	...	...	...	...	...
Light field hygiene section ...	...	...	...	...	...	1	...	...	...	...	...	...	...	...
CCS	1	1	1	...	...	...	...	...	...	...	...	...	...	...
General hospital (combined) (3 Indian and 1 British sections)	1	1	1	1	...	...	...	...	...	...	...	...	...	...
General hospital (combined) (5 Indian and 2 British sections)	2	1	2	1	...	...	...	...	...	...	...	...	...	...
General hospital (combined) (7 Indian and 3 British sections)	3	1	2	1	...	...	...	...	...	...	...	...	...	...
General hospital (Indian troops 600 beds)	2	1	2	1	...	...	...	...	...	...	...	...	...	...
General hospital (Indian troops 1,000 beds)	3	1	2	1	...	...	...	...	...	...	...	...	...	...
Base general hospital (Indian troops 1,000 to 1,400 beds)	4	2	2	1	...	...	...	...	...	1	1	...	...	...
Base general hospital (Indian troops 1,500 beds) ...	4	2	3	1	...	...	...	...	...	1	1	...	...	...
Base general hospital (British troops 800 to 1,200 beds) ...	3	2	2	1	1	...	...	...	...	1	1	...	...	...
Base general hospital (British troops 1,300 to 2,000 beds)	4	2	3	1	1	...	...	...	...	1	1	...	...	...
Field hospital	1	...	...	...	...	...	...	...	...	...	...	...	...	...
Beach medical unit ...	1	...	...	...	...	...	...	...	...	...	...	...	...	...
Field laboratory ...	...	...	...	...	1	...	...	...	...	...	...	...	...	...
Ophthalmological unit ...	...	...	...	...	...	...	...	...	...	...	1	...	...	...
Maxillo-facial unit ...	2	1	...	...	...	...	...	...	...	...	...	...	...	...
Mobile surgical unit ...	1	1	...	...	...	...	...	...	...	...	...	...	...	...
Surgical unit ENT ...	...	...	...	...	...	...	...	...	...	1	...	...	...	...
Mobile X-ray unit ...	...	...	...	1	...	...	...	...	...	...	...	...	...	...
Typhus research team ...	...	...	...	...	1	...	...	...	...	...	...	...	...	...
Hospital ship *Tairea* ...	1	1	1	1	...	...	...	...	...	...	...	...	...	...
Hospital ship *Karapara* ...	1	1	1	1	...	...	...	...	...	...	...	...	...	...
Hospital ship *Karoa* ...	...	...	1	...	...	...	...	...	...	...	...	...	...	...
Hospital carrier *Melchior Trueb*	1	1	1	...	...	...	...	...	...	...	...	...	...	...
MFTU	...	...	1	...	...	...	...	...	...	...	...	...	...	...
Hospital coastal steamer Wu-Sueh ...	1	1	1	...	...	...	...	...	...	...	...	...	...	...
Orthopaedic wing (British troops 500 beds) ...	5	...	...	1	...	...	...	...	...	...	...	...	...	...
Orthopaedic wing (British troops 1,000 beds) ...	10	...	...	1	...	...	...	...	...	...	...	...	...	...
Orthopaedic wing (Indian troops 200 beds) ...	2	...	...	1	...	...	...	...	...	...	...	...	...	...

Units	Surgeons	Anaesthetists	Physicians	Radiologists	Pathologists	Hygienists	Venereologists	Psychiatrists	Dermatologists	Otologists	Ophthalmologists	Malariologists	Gynaecologists	Neurologists
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Orthopaedic wing (Indian troops 300 beds) ...	3	...	...	1	...	...	...	...	...	...	...	...	...	...
Orthopaedic wing (Indian troops 500 beds) ...	5	...	...	1	...	...	...	...	...	...	...	...	...	...
Orthopaedic wing (Indian troops 1,000 beds) ...	10	...	...	1	...	...	...	...	...	...	...	...	...	...
Venereal diseases clinic, Calcutta	...	...	...	...	...	...	3	...	...	...	...	...	...	...
Malaria research unit (prevention)	...	...	...	...	...	...	...	...	...	...	...	1	...	...
Central military pathological laboratory		...	...	...	4	...	...	...	...	...	...	...	...	...
Malaria research unit (clinical)	...	...	...	...	1	...	...	...	...	...	...	...	...	...
District laboratory ...	...	...	...	...	1	...	...	...	...	...	...	...	...	...
Army school of hygiene ...	...	...	...	...	...	6	...	...	...	...	...	1	...	...
POW hospital	2	...	2	...	...	...	...	...	...	...	...	...	...	...
Serological laboratory ...	...	...	...	...	2	...	...	...	...	...	...	...	...	...
Dysentery team	...	...	...	...	1	...	...	...	...	...	...	...	...	...
Artificial limb centre ...	1	...	...	...	...	...	...	...	...	...	...	...	...	...
Mass radiography centre ...	...	...	...	1	...	...	...	...	...	...	...	...	...	...
Penicillin research team ...	...	...	...	...	1	...	...	...	...	...	...	...	...	...
Base typhus research team ...	...	...	...	...	1	...	...	...	...	...	...	...	...	...
Anaemia investigation team...	...	...	...	...	1	...	...	...	...	...	...	...	...	...
Biochemical research team ...	...	...	...	...	1	...	...	...	...	...	...	...	...	...
Parasitological research team	. .	...	...	...	1	...	...	...	...	...	...	...	...	...
War wounds research team ...	1	...	...	...	...	...	...	...	...	...	...	...	...	...
Inspectorate of food stuffs ...	...	...	...	...	...	9	...	...	...	...	...	...	...	...
Garrison hospital India ...	102	67	102	67	...	...	89	...	...	...	...	...	17	...
Garrison hospital SEAC ...	5	4	5	4	...	...	...	...	...	...	...	...	...	...
Pool of specialists ...	...	...	...	...	...	...	...	70	39	14	14	...	...	...
Medical staff appointments—														
India	6	5	9	4	42	1	14	1	1	1	2	21	...	2
SEAC	8	3	3	...	21	1	1	1	1	...	...	19	...	...

With a view to co-ordinate and supervise the work of specialists, the following appointments of consultants and advisers were made. In most cases these appointments were authorised at a very late stage.

Designation	*Date of appointment*
Consultant surgeon	15 January 1942.
Consultant physician	23 April 1942.
Consultant psychiatrist	23 April 1942.
Inspector of Medical Services ...	23 April 1942. Originally sanctioned as Inspector of Hospitals.
Consultant malariologist (Honorary) ...	23 April 1942.
Consultant neurologist	5 February 1943.
Consultant ophthalmologist	17 July 1943. Originally sanctioned as adviser in ophthalmology on 22 December 1941.
Consultant in nutrition (Honorary) ...	27 November 1943.
Consultant anaesthetist	26 August 1944. Originally sanctioned as adviser in anaesthetics on 29 May 1942.
Consultant in oto-rhino-laryngology ...	25 September 1944. Originally sanctioned as adviser on 11 November 1942.

Designation	*Date of appointment*
Consultant dermatologist	31 October 1944. Originally sanctioned as adviser on 5 September 1942.
Consultant radiologist	31 October 1944. Originally sanctioned as X-ray adviser on 16 July 1941.
Consultant venereologist	31 October 1944. Originally sanctioned as adviser on 21 July 1943.
Assistant to consultant surgeon ...	28 March 1945.
Assistant to consultant physician ...	28 March 1945.
Adviser in neurosurgery, India Command	6 April 1945.
North Western Army—	
Consultant physician	27 January 1943. (also of Central Command).
Adviser in anaesthetics	6 September 1944.
Adviser in dermatology	4 April 1945.
Adviser in venereology	4 April 1945.
Adviser in oto-rhino-laryngology ...	4 April 1945.
Adviser in radiology	4 April 1945.
Southern Army—	
Consultant surgeon	18 December 1941.
Consultant ophthalmologist	23 April 1942.
Consultant physician	23 April 1942.
Consultant oto-rhino-laryngologist ...	23 April 1942.
Adviser in neurology	29 February 1944.
Adviser in psychiatry	23 June 1944.
Adviser in anaesthetics	11 August 1944.
Adviser in dermatology	4 April 1945.
Adviser in ophthalmology	4 April 1945.
Adviser in venereology	4 April 1945.
Adviser in oto-rhino-laryngology ...	4 April 1945.
Adviser in radiology	4 April 1945.
Central Command—	
Consultant physician	27 January 1943 (also of North Western Army).
Consultant surgeon	20 October 1944.
Adviser in psychiatry	23 June 1944 (also of North Western Army).
Adviser in anaesthetics	11 August 1944.
Adviser in dermatology	4 April 1945.
Adviser in venereology	4 April 1945.
Adviser in oto-rhino-laryngology ...	4 April 1945.
Adviser in radiology	4 April 1945.
Eastern Command—	
Consultant physician	30 November 1942.
Consultant surgeon	27 January 1943.
Adviser in psychiatry	23 June 1944.
Adviser in anaesthetics	11 August 1944.
Adviser in dermatology	4 April 1945.
Adviser in venereology	4 April 1945.
Adviser in oto-rhino-laryngology ...	4 April 1945.
Adviser in radiology	4 April 1945.
Adviser in ophthalmology	4 April 1945. (also of Central Command).
Adviser in neurology	4 April 1945.

CONFERENCES

In order to provide opportunities to the specialists to meet and discuss common medical problems, conferences were arranged. The first military medical conference in India during the war was held in the Southern Army in February 1943. Subsequent conferences were held at Ranchi, Eastern Army, in March 1943, Bangalore, Southern Army, in the autumn of 1943, Lahore, Central Command and North-Western Army in February 1944, Poona, Southern Army, in April and

May 1944, Agra, Central Command and North-Western Army, in November 1944, and Ranchi, Eastern Command, in April 1945. A very successful conference was also held by the Fourteenth Army physicians at Comilla in February 1944. Similar conferences were held by surgeons and pathologists. The need for the development of a close liaison with the civil medical institutions and practitioners was stressed. One outcome of this was the inauguration of the Bombay Medical Congress which was held in the Grant Medical College, Bombay, in June 1943. It proved very successful and an attendance of 1,000 was recorded. The second and third medical congresses were held in February 1944 and August 1945.

GENERAL OBSERVATIONS

Figures, from official records, have been quoted to give an overall picture of various diseases and disorders. It must, however, be stated that the conditions prevailing, especially during 1942 and 1943, were such that compilation of accurate statistics was not always possible. The scope and significance of data, therefore, have obvious limitations.

Certain lessons emerge from the above available figures and observations. The considerable wastage of manpower in early days of the war would have been avoided if detailed planning had been done before or at least at the very outset of the war. The importance of close liaison of pathology service with specialist services was again brought to the fore. As the contributor of the pathology section of this volume has observed "the ability of the pathologist must be harnessed and geared to the specific needs of the armed forces". This observation applies to development and planning of all branches of medicine. The members of medical services are not only responsible for medical planning, but as a vital part of the armed forces, are very much concerned with general staff planning. It was repeatedly observed during the war that the medical services must be consulted at every stage by the general staff if catastrophies were to be avoided.

The lessons of history are, however, often forgotten. The study of medical history and medical geography are essential for the success of any campaign. The material on medical geography was and still is very limited. The information on physical, social and epidemiological factors is of utmost importance before any adequate medical appreciation can be prepared.

The outstanding feature of the casualty figures is not only that the diseases account for more casualties than war wounds but also that majority of them are preventable. Some of them would have been avoided if the medical services were consulted in time.

The medical services not only devote their energies towards preventive medicine but endeavour to make available the best aid that science can provide to the sick and wounded. The importance of research for the conservation of manpower and for the provision of adequate treatment cannot be overemphasised. Protective inoculation of all ranks in all areas against smallpox, typhoid, paratyphoid A and B

and tetanus; and against plague, cholera, yellow fever and typhus in areas where there was risk from these diseases, and control of diseases like malaria and typhus reduced the morbidity and mortality figures. Side by side, the advances in the rapid evacuation of casualties especially by air, arrangement of skilled surgical and medical aid in forward areas, especially provision of blood and plasma for transfusion, sulpha drugs and penicillin, X-ray, laboratory and mobile surgical units, brought the expert aid to the soldier in the shortest time possible and increased his survival rate. It became necessary to familiarise every medical officer with the medical problems of every theatre of operation and improvement in the methods of treatment. Dental, neurosurgical, orthopaedic and physiotherapy were some of the other services introduced during the war.

The difficulties of manpower during a war cannot be tackled unless enough trained medical manpower is available in the country. Similarly difficulties of providing stores and equipment cannot be overcome until the industry in the country is able not only to produce the equipment required in peace but is able to expand rapidly to meet the war-time demands.

It must be stated that, despite all the difficulties, a well-organised medical service was gradually established and all the ranks of the medical services as a whole emerged triumphant in the end. The success in any emergency in the future will obviously depend on not repeating the mistakes committed in the past and in planning ahead.

Finally, observations made in *Medical Research in War* 1939-45 (His Majesty's Stationery Office, London) may be repeated, for these very well sum up an important aspect of the medical profession in relation to war:

> " War in a sense is perhaps a greater challenge to medicine than to other sciences, because the original motive which guides men and women into the field of medical research, or indeed into medical work of any kind, is a desire to reduce human suffering and to prevent untimely death. With the outbreak of war they realise that the dominant world forces are now those that involve increased suffering and are concerned to end life. In special degree, therefore, the medical worker sees all his ideals threatened with annihilation, and quite apart from the patriotic spirit that he shares with other members of the community he is faced by a particular challenge. The history of war is, in one sense largely a race between the development of instruments of physical destruction and the advancement of medical knowledge for saving the life of wounded and sick men. If a strict comparison were made between what science has done to increase war mortality and what medical science done to lessen these lethal effects, there is good reason to believe that the latter would be an easy winner. No man with any knowledge of the history of disease in relation to war would ever say that science is wholly given to the forging of instruments of destruction ....indeed until the introduction of atomic weapons in the final stage the claim that the advance in the saving of life in war time had been at least as great as the advances in the methods of destruction would not be unreasonable ".

CHAPTER II

Anaemia

Anaemia as a cause of disability in Indian troops finds no mention in the official history of World War I. During World War II one-quarter and sometimes even one-third of the total casualties occurring among Indian troops serving in Assam, Burma and India resulted from anaemia and malnutrition. This paradox appears less remarkable on further examination. During World War I, the Indian Army expanded to less than one-third the size attained during the last war and the economic structure of the country was little disturbed. In World War II very different conditions prevailed. The enormous expansion of the army necessitated the recruitment of so many fighting men that the former standards of physique had to be relaxed, while to supply large deficiencies in the transport and pioneer units, classes of Indians of low economic and physical status never before recruited were enrolled in large numbers. Such men came largely from the South India, Bihar, Orissa, and Bengal. The occupation of Burma and Malaya by the Japanese caused a disruption of the internal economy of the country with consequent food shortages and rising cost of living, the brunt of which fell inevitably on the poor agricultural and labouring classes, whose nutritional state even in favourable times was precariously maintained.

The subject of anaemia in Indian troops with its frequent associate malnutrition, requires examination under two heads, that found initially in men under training and that which developed in soldiers under active service conditions.

SURVEY IN KOHAT AND THAL

Troops returning from Burma were suffering from malaria and dysentery. Over 20 per cent. of troops from Burma in Kohat showed malaria parasites in their blood. They had been on inadequate rations due to supply difficulties. On return to garrison stations they were placed on peace scale of rations with a meagre messing allowance. The rations were very poor in animal proteins and due to rising price the ration could not be adequately supplemented from messing allowance. The nutritional reserves were depleted and recuperation was slow. Nutritional survey in Kohat and Thal showed not only high rate of anaemia but frank deficiency diseases specially due to lack of vitamin B.

INVESTIGATION IN NORTHERN INDIA

The condition of men under training in Northern India was exhaustively investigated by a GHQ research team stationed in Rawalpindi between September 1943 and January 1945 (Hynes, 1944). Among Indian soldiers in the Peshawar District a high incidence of iron deficiency anaemia was found in the Punjabi units, two-thirds of whose

men showed a prompt therapeutic response to iron. The anaemia was hypochromic and commonly normocytic, though occasionally microcytosis was seen. Men of pre-war recruitment showed a significantly higher haemoglobin level than the men with shorter service. A survey of 1,118 Punjabi sepoys showed that 15 per cent. had a haemoglobin concentration of less than 12 g./100 c.c., 70 per cent. between 12 g. and 14 g./100 c.c., and only 14 per cent. could be considered really robust with a concentration in excess of 14 g./100 c.c. The incidence of anaemia bore no relationship to class or creed. Ancylostomiasis was proved as cause of anaemia in only one-third of the anaemic men, in whom, however, it appeared to be an important aetiological agent in that there was good correlation between the load of ova and the degree of anaemia, while even those who were but lightly infected showed a significantly lower haemoglobin concentration than men free from this parasite. The primary causal factor must, therefore, have been a deficient assimilation of iron, despite the provision of about 52 mg. of this metal in the full daily ration.

The haematological status of recruits was determined by examination of 600 men at the Indian Army Medical Corps (IAMC) Depot, Rawalpindi, in 1943. In these, a mild iron deficiency anaemia showing a dramatic response to iron therapy, was widespread, while the characteristic findings were normocytosis and normochromia. Ancylostomiasis was a contributory cause only, the main factor again being a deficient iron intake. That this deficiency was primarily dietetic was suggested also by a comparison of the results obtained from Punjabi nursing sepoys who were drawn from better educated and more prosperous social classes than the other types represented, namely Punjabi and the United Provinces ambulance sepoys and ward servants or Madrassi sweepers. Such nursing sepoys showed a much higher haemoglobin level than did men of the other classes.

The effect on the haemoglobin level of army training and diet alone and when supplemented with iron (6 g. of ferrous sulphate daily) was tested in two comparable groups of recruits. The control group receiving army diet and no iron showed a slow improvement during a three months period, in which the proportion of those anaemic (haemoglobin concentration of less than 13 g./100 c.c.) fell from 45 per cent. to 32 per cent., while the proportion of those whose haemoglobin concentration was above 14 g./100 c.c. rose from 24 per cent. to 50 per cent. The iron supplement led to a much greater and more rapid improvement, for during the same period, in the group taking ferrous sulphate the proportion of anaemic men fell from 47 per cent. to 8 per cent. while that of men of over 14 g./100 c.c. rose from 23 per cent. to 80 per cent.

This widespread iron-deficiency anaemia in both the trained soldiers and recruits in the Northern India stimulated investigation into the factors leading to deficient assimilation of iron from a diet which contained at least three times the daily requirements. While these investigations were carried out in the units under training in Rawalpindi and Abbotabad districts only, it is not unreasonable to assume that

inferences drawn from them were equally applicable to most other training areas.

In an Indian diet, iron is derived from *atta* or whole meal flour, *dal* or lentils, green vegetables and meat. Analysis of samples of these substances taken from the local units showed the iron content of the standard army daily ration to be 42 mg.

TABLE I

Iron content of the standard daily rations—Indian diet.

Food	Daily ration in oz.	Iron content in mg.
Atta	24	26
Dal	4½	10
Green vegetables ...	8	5
Meat	5	1

All this iron was, however, not available for physiological use. The experiments *in vitro* suggested that from 36 mg. iron provided by the *atta* and *dal* components of the diet, amounts varying from 14·8 mg. to 29 mg. only could be utilised. The former figure was obtained by digesting the ration with hydrochloric acid and pepsin in amounts equivalent to the normal gastric contents, and the latter with a similar amount of hydrochloric acid and an excess of vitamin C. Proof was thus furnished that the ration provided adequate available iron, in case it was eaten in full. An inquiry was next made into the proportion of the authorised diet actually eaten by men in the units concerned. Despite a directive to all the units in the North Western Army that three main meals a day should be given, it was found that this was not always carried out. Observations showed that Indian soldiers habitually ate far less than the authorised rations. The average figures of rations actually consumed were *atta* 13 oz. out of a 24 oz. issued (54·16 per cent.) and *dal* 3½ oz. out of a 4½ oz. (77·77 per cent.).

The institution of an extra early morning meal and *halwa* or pudding every second day increased the optimal amount of *atta* intake to 19-20 oz. daily.

These differences between the values in practice obtained and those theoretically supplied, adequately explained the inconsistent finding of iron deficiency anaemia on a diet rich in that substance. Thus instead of 3,830 calories, the men obtained on an average 2,680 calories a day; the protein intake was in practice 78 g. instead of 118 g., while the intake of available iron might have been as low as 8·8 mg., a figure considerably below the minimum requirement (12 mg. to 15 mg.) for health.

The appointment of nutrition officers to many units in 1944, and efforts made to step up the intake of *atta* and *dal* by the introduction of *halwas* and *parathas* into the menu resulted in a greatly improved utilisation of the ration subsequently. This was reflected in the steady

improvement in the nutritional status of men in several units while under serial observation.

The work of the research biochemist attached to the anaemia investigation team at Rawalpindi revealed another interesting fact: investigation of gastric function in cases of bacillary or clinical dysentery showed that after a short latent interval the secretion of both acid and pepsin was temporarily suppressed for a period of about one week from the beginning of the illness. Administration of a fluid diet and sulphaguanidine to non-dysenteric controls did not cause a similar suppression which, therefore, seemed to be an effect of the dysenteric infection itself. Oral and parenteral nicotinic acid, given from the earliest stage of the illness did not prevent this phenomenon. Other vitamins were not tested. Transient achlorhydria and apepsia following dysentery may well add to the iron deficiency of individuals taking a sub-optimal diet.

INVESTIGATIONS IN MYSORE STATE

An investigation on the South Indian recruits was carried out on similar lines by the same research team in 1945, working at Harihar in Mysore State. Iron deficiency anaemia with evidence of general malnutrition was the characteristic finding. The anaemia was usually normocytic and normochromic, though rare examples of mild macrocytic anaemia were found. There was clear correlation between the blood condition and the degree of muscular development, anaemia being least common in the men with good physique and most common in those who were poorly developed. In addition, anaemia was inversely related to the amount of subcutaneous fat present, those men with least fat (and relatively more muscle) having a higher haemoglobin level than fatter men with less muscle.

It is suggested that haemoglobin production and muscle development are related to protein intake, while fat deposition depends upon non-protein calorie intake. Deviation of the diet towards the latter type leads to a flabby and anaemic though well-padded individual, while a higher protein diet produces a muscular man with a satisfactory blood picture.

Evidence of mild vitamins A and B_2 deficiency was observed. The eyes of many men showed xerosis with pigmentation and increased vascularity of the conjunctiva. Their skin tended to be dry and scaly with hyperkeratosis follicularis and phrynoderma. Anaemia was common in individuals showing these changes, and was regarded as manifestation of a general dietetic deficiency. Contributing causes to the anaemia were ancylostomiasis and chronic malaria of which evidence was found in only a few cases.

In general it can be said that the recruits who entered the army in the later years of the war came of an iron deficient stock. This deficiency was accentuated in about one-third by ancylostomiasis, chronic malaria and dysentery, while, prior to 1944, it is probable that few ingested a sufficient proportion of the generous army ration to restore their blood picture to normal.

The anaemia which developed in Indian soldiers on active service has aroused much interest, through its universality, its severity, and the fact that it has been predominantly macrocytic. It is abundantly clear that this acquired anaemia led to a serious wastage of vital man-power in every theatre of war in which Indian troops were engaged. It was common not only in operational areas but in lines of communication and base units also. The disease was common in the Iraq-Iran Force. It was encountered in the Middle East, Burma-Assam border and Burma and reached nearly disastrous proportions during the retreat from Burma. That the same type of disease appeared in World War I, is suggested by the following passage in the *History of the Great War** which also shows that the malnutritional basis of the anaemia described was not recognised. " Post-malarial anaemia was generally of the pernicious type with poikilocytes, megaloblasts and even myelocytes: in fact it might resemble pernicious anaemia or leucocythemia very closely indeed "

IRAQ-IRAN AREA

Since the clinical picture in the cases drawn from the Burma-Assam field is complicated by multiple inter-related factors of vitamin deficiency, malaria and dysentery, it is best to direct attention first to the Iraq-Iran area. In this theatre, after sharp initial operations, there was no further fighting, supply lines were good and easily maintained, rations were plentiful and the troops endured little real hardship. In addition, malarial control was efficient and dysentery showed a negligible incidence in the Indian troops. Considerable numbers of men became anaemic, among whom vegetarians greatly predominated. Taylor and Chhuttani (1945) reported that the incidence of anaemia of all types, though mainly macrocytic, was twenty-two times higher in vegetarians than in men who took the same diet with an additional 5 oz. of meat ration. Scott and Brafield (1944) observed : " We were surprised to find in Iraq that almost all the severe anaemias that occurred in non-meat eaters were macrocytic and were very often not associated with the usual concomitant factors such as hookworm and malaria ". This investigation was made among a group of 177 fit Indian vegetarians, mostly transport drivers working on the very strenuous " aid to Russia " route from the head of the Persian Gulf to the Caspian Sea. They excluded all men who had any recent illness. These men showed high incidence of anaemia.

TABLE II

Incidence of Anaemia in 177 fit Indian vegetarians.

RBC concentration in millions per c. mm.	Percentage of men
Over 5·0	23
4·6-5·0	46
4·1-4·5	17
3·6-4·0	7
3·0-3·5	7

**History of the Great War, Medical Services,* Diseases of the War, Vol. I, p. 269.

A control group of meat eaters engaged on the same duties but chosen at random showed an average red cell count of 5 million per c.mm. All those men whose count was below 4·6 million were given one pint of milk daily in addition to their standard diet; after 4 weeks on this regime, half of them had attained a normal blood picture. Fifty-one men who failed to respond satisfactorily to the additional milk were found still to show red cell counts of 3·0-4·5 million per c.mm. with macrocytosis (mean corpuscular volume 94-141cμ, average 111cμ). Further treatment with milk and injection of liver extract totalling 14 c.c. resulted in a return of the blood picture to normal in all of them after three weeks. Nevertheless, a follow-up of 12 men of this latter group, showed that 6 months after their return to their unit, seven of them had relapsed and an estimation of the mean corpuscular volume of four of them gave values of 105, 113, 119 and 127cμ. Conversely, a State force unit which had served in a static role for 3½ years under better dietetic conditions, showed no anaemia among 60 vegetarian soldiers selected at random. All men of this unit had, however, received an additional ration of 2½ to 4½ oz. of condensed milk daily, and were able to buy fresh milk in the canteen, an advantage which mobile units were unable to enjoy.

Instances of this tendency of vegetarian troops to develop macrocytic anaemia were observed also in Egypt. For example, in a battalion, whose composition was two-third Jats (vegetarians) and one-third Rajputana mussalmans (non-vegetarians), which was stationed in a base area, 16 cases of grave macrocytic anaemia were treated, every one of whom was a Jat while the mussalmans were found to be healthy.

Yeast in the form of marmite, was generally available in the Middle East as an additional ration item, and was used by many Indian units with good effect. In addition, supply depots held large stocks of compressed yeast tablets. This preparation was found of therapeutic value in cases of macrocytic anaemia, an advantage being that such tablets were free from the saltish meaty taste of marmite which rendered it objectionable to many vegetarians.

Three typical case histories may serve to illustrate further the condition. A well-built Jat havildar who was admitted to No. 32 CGH, Iraq, after six months service in that country, was found to have a red cell concentration of 7,60,000 per c.mm. with a haemoglobin concentration of 16 per cent. Sahli: the anaemia was macrocytic and hypochromic. He was treated for this very disease in Rawalpindi in 1937, after he had been on frontier operations for 6 months, which shows that macrocytic anaemia in serving Indian soldiers occurred prior to the recent war though in numbers too small to arouse comment. A Jat *sowar* was treated in the same hospital for macrocytic anaemia and was discharged to his unit with a normal blood picture in April 1943. The same man was received in a convoy from Italy at No. 18 IGH, Egypt, in October 1943, and was found to show a grossly macrocytic anaemia which was even more grave than that observed on his first admission. A Jat sepoy was received at No. 2 IBGH, Kirkee (India), in a convoy from England as a case of aplastic anaemia, with

the following blood picture: RBC 1·26 million per c.mm. haemoglobin (Hb) 2·9 g./100 c.c. colour index (CI) 0·8, macrocytosis and hypochromia. This man had undergone long periods of treatment for the same conditions in Egypt in 1941, and in Iraq in 1942, and after evacuation to India had finally been drafted to England where his second relapse had occurred. He made a slow but complete recovery on transfusion and liver therapy.

All these men were free from hookworm, none had chronic malaria, their gastric secretion was normal and general nutrition was good. They served to illustrate the following points :—

(i) Macrocytic anaemia occurred in vegetarian troops on the active service scale of rations, but could be prevented by an increased protein intake in the form of milk.

(ii) A period of about 6 months elapsed before the condition became so severe as to render them unfit for duty.

(iii) Relapses occurred after the same period when they resumed their former dietetic habits.

(iv) With each relapse, the anaemia tended to become more resistant to treatment.

(v) Uncomplicated anaemia was usually not associated with wasting or with evidence of other specific vitamin deficiency.

ASSAM—BURMA THEATRE[1]

In the Assam-Burma theatre of war the problems presented by anaemia in the Indian troops were both grave and complex. The multiple inter-related factors included initial low haematological reserves, dietetic deficiencies in certain areas and diseases, notably malaria and dysentery. The widespread, though mild, iron deficiency type of anaemia found among the recruits and trained men in certain depots in the Punjab has already been mentioned. Additional evidence was furnished by Pasricha (1944) who carried out a rapid survey of a group of trained men who were ready to be sent on active service from a regimental depot in the United Provinces in 1943. Despite their satisfactory muscular development, estimation by the Tallquists' method suggested that all had a haemoglobin concentration of below 60 per cent., while 70 per cent. showed a level below 50 per cent. In spite of the notorious inaccuracy of this method, there can be no doubt that these men were anaemic. It seems justifiable to assume that in 1942, Indian soldiers as a whole entered an area of extremely rigorous combat, ill-equipped physically to endure privation and the added burden of disease.

Dietetic deficiency was restricted to the most inaccessible areas in the interior of Assam and was conditioned by the inadequacy of communications across a most difficult terrain, for air supply was at that time only just being developed. Taylor (1944) stated that the notably higher incidence of sickness in Indian soldiers as opposed to

[1] A review of 500 cases of anaemia is given in Appendix A.

British troops was attributable to a deficiency of animal protein, fresh fruit and fresh vegetables in the ration of the former, whereas the latter were largely protected by supplies of bully beef, which was unacceptable to the Indian soldiers. The quantity of milk was not probably adequate in the ration for vegetarians. Indian units operating in Arakan, being within reach of sea-borne supply lines, did not suffer from malnutrition. Shortage of fresh foodstuffs became acute in Assam after May 1943, and by October this factor together with a high incidence of malaria had filled local hospitals with about 1,000 cases of anaemia and sprue syndrome, while many others had overflowed into the Central Command.

In 1944, the staff captain (nutrition) to the Fourteenth Army discussing the difficulty in implementing the full field service scale of rations for Indian troops, arising from insuperable difficulties of transporting large amount of bulky fresh foodstuffs and the lack of sufficient tinned and dehydrated substitutes, gave a list of rations as actually received in certain units, against the authorised scale.

TABLE III

Issues of fruits, meat and vegetables authorised and actually received in the Fourteenth Army—1944.

Items	Issues authorised per week	Items	Issues received per week (Actual average)
Fruit, fresh	7	Fruit, fresh Sugar, cane, Fruit, dried	2 1 4
Meat, fresh	4	Meat, fresh *Atta* and *ghee* Meat, dehydrated	½ 2½ 1
Onions, fresh	7	Onions, fresh Onions, dried Vegetable, dried	3 2 2
Potatoes, fresh	7	Potatoes, fresh Potatoes, dried	1½ 5½
Vegetables, fresh	7	Vegetables, fresh Vegetables, tinned *Dal*, whole	3 3 1

Shortages of fresh foods were largely made good later by the production, under army sponsorship, of large amounts of fresh vegetables and dehydrated foodstuffs and the importation of tinned supplies. The dehydrated foodstuffs were often of impaired vitamin content, and in the case of meat products, not much liked by the Indian soldiers.

The most potent precipitating disease in the production of anaemia was recurrent malaria, evidence of which was found in 80 per cent. of a series of 200 cases of grave anaemia which passed through the hands

of one physician during 1942 and 1944 (Passmore, 1944). The importance of the malarial factor is borne out by the striking haematological response evoked by anti-malaria treatment alone, examples of which are given in Table V.

TABLE IV

Analysis of average diet issued daily and optimum requirements. Fourteenth Army—1944.

	Average quantity in diet issued	Optimum net daily requirements
Proteins g.	112–114	100
Animal proteins g. ...	14–21	40
Calories	4,060–4,360	4,000
Calcium mg. ...	600–740	800
Iron mg.	55–58	15
Vitamin A. (I.U.) ...	2,790–3,480	4,000 (2,000 minimum)
Vitamin B_1 mg. ...	1,220–1,320	900
Riboflavin mg. ...	1·9–2	2·7 optimum (1·0 minimum)
Nicotinic acid mg. ...	40–41	23
Ascorbic acid mg. ...	55–75	75

TABLE V

Haematological response to anti-malaria treatment.

Case number	Type of malaria	RBC in millions/c.mm.		Hb. in g./100 c.c.	
		Initial	Final	Initial	Final
1	MT	2·0	3·7	5·5	10·6
2	BT	2·2	4·2	5·8	11·0
3	BT	1·8	3·5	6·0	11·4
4	Not found	0·8	3·2	3·0	7·2
5	BT and MT	1·7	3·3	4·5	9·6

There was haematological response to a single standard anti-malaria course (quinine grains 10 *t.d.s.*—2 days, mepacrine 0·1 mg. *t.d.s.*—5 days, pamaquine 0·01 mg. *t.d.s.*—5 days). All patients received no other drug and were on convalescent diet. The final estimations were made within 20 days of the commencement of the course.

It was suggested that the most important action of malaria in the genesis of anaemia lay in its power to inhibit the bone-marrow, which was found characteristically to exhibit arrest of maturation at the early and intermediate normoblast stages, leading to slight macrocytosis. This condition may in rare instances progress to definite marrow aplasia.

Whereas recurrent malaria was of paramount importance as the precipitating agent of anaemia in Indian soldiers in whom a scanty

intake of animal protein led to low haematological reserves (Marriot, 1944), among British soldiers malaria produced no such effect. Leishman and Kelsall (1944), reviewing 2,819 cases of malaria in British troops, observed that "chronic anaemia and persistent splenomegaly were rarely seen, even in patients who have had as many as fifteen attacks of malaria in as many months."

Dysentery provided a factor only slightly less important than malaria but the marked seasonal incidence of anaemia, which rose abruptly during the monsoon months, when both malaria and dysentery were rife, renders the individual evaluation of either factor difficult. In certain instances dysentery seemed to provide the more important immediate factor, as was shown by the sudden appearance of anaemia and malnutrition in the fighting troops of the 7th Indian Division following an epidemic of dysentery in May 1944 (Smith, 1944). The 5th Indian Division on similar diet, which remained free from dysentery, was not affected. In a single infantry battalion evacuated in August 1944, from the Kohima area, dysentery appeared to have precipitated anaemia in some 70 per cent. of the 42 cases of severe malnutrition, whereas malaria was held to have been responsible for 25 per cent. only (Walters, 1947).

Ancylostomiasis, while a prominent cause of anaemia amongst recruits, contributed little to the number of anaemic patients from the fighting areas, since the infection generally tends to die out naturally after one year's army service. This fact is reflected in the decreasing incidence of ancylostomiasis with increasing period of service (Vasey, 1944). It may be added that the duration of life of *A. duodenale* is variable. It may be a few months or as long as seven years.[2]

TABLE VI

Diminution of the incidence of anaemia (per cent) due to ancylostomiasis in relation to service.

Cause of anaemia	Service in army		
	0-1 year	1-2 years	Over 2 years
Hookworm	47	33	20
Hookworm and malaria ...	44	39	15
Others	33	36	31

In addition to the cases of anaemia admitted to the hospitals direct from the operational areas, a new type of patients began to appear in the garrison hospitals all over India in 1943. These cases were seen among men who reported at their training centres on completion of war leave in a state of malnutrition and anaemia. A physician at the Indian Military Hospital (IMH), Delhi, where 370 such patients were admitted during the months of September and October 1944, graphically describes them as "weary, wan and green-clad, recognisable on sight"

[2] See page 69.

(Bellmaine, 1945). Many such men were undoubtedly suffering from marasmus and chronic diarrhoea at the time when they went on leave, but this was not reported lest their chances of obtaining leave should be prejudiced. Such diarrhoea was usually of the sprue type, primarily of nutritional origin but precipitated by actual dysentery, and was accompanied by a sore red tongue and marked anaemia. The anaemia, which was often extreme, was characteristically macrocytic.

The anaemia, shown by Indian soldiers from the eastern battle zone, being the result of multiple factors, followed no standard pattern though the macrocytic form predominated. Lehman observed that in about one-third of such cases there was a superimposed iron deficiency, shown by a mean corpuscular haemoglobin concentration (MCHC) of less than 28 per cent. This was usually due to ancylostomiasis with malaria as an added factor in many cases. Practically all cases with a haemoglobin concentration below 60 per cent. (Sahli) were of the dimorphic type, and showed a megaloblastic reaction with deficient haemoglobinisation of the red cell precursors (Girdwood, 1945).

Salient features reported from all hospitals which received such cases were the severity of the anaemia and the slow response to treatment.

One anaemia centre confined its attention to those patients whose haemoglobin concentration was less than 6 g./100 c.c., its 100 beds fully occupied throughout, while another physician elsewhere in 6 months treated 200 cases of grave anaemia, among whom 56 showed a haemoglobin level of less than 3 g./100 c.c.

A red cell concentration of less than 2 million per c.mm., was usually accompanied by fever, which ceased as the count rose, and by transient achlorhydria (Harvey, 1944). The reticulocyte response to both crude and refined liver extracts was generally very disappointing, especially in cases with a RBC count of below 2 million per c.mm., while vegamite, marmite and compressed yeast tablets proved equally ineffective.[3]

Transfusion of fresh blood appeared essential to stimulate reticulocytosis as liver therapy was ineffective in such cases. Before transfusion technique was improved and standardised by the formation of large base transfusion units in 1943, a high incidence of adverse

[3] Considerable amount of work has since been done on cases refractory to parenteral liver therapy and oral iron. Reference may be made to vitamin B_{12} and the preparation of iron for intravenous use.

Rickes, Brink, Koniuszy, Wood & Folkers (1948a) and Smith (1948) isolated a crystalline compound, B_{12} from liver. This compound appears to be the main active principle in liver extracts. Rickes *et al.* (1948b) further isolated B_{12} from cultures of *Streptomyces griseus*. Patel (1948) reported satisfactory response to B_{12} in nutritional macrocytic anaemia. On the other hand, there are cases which are refractory to both liver extracts and B_{12}. Mueller, Hawkins & Vilter (1949) have reported such a case, which finally responded to folic acid. Girdwood (1950) has made an excellent review of the literature on vitamin B_{12}.

Slack & Wilkinson (1949) and Govan & Scott (1949) have favourably reported on the efficacy of ferrivenin (a proprietary preparation of Bengers Ltd.). Davidson & Fullerton (1950) have, however, pointed out that "frequently patients who have been regarded as refractory to iron as out-patients respond very satisfactorily to the same dose of the same preparation in hospital. It may well be that one of the main advantages of intravenous iron is that its use ensures that the prescribed dose of iron has in fact been administered". This experience is shared by many other workers.

reactions and post-transfusion deaths caused this vitally important measure to fall into disrepute, and led to the suggestion that concentrated RBC suspensions should be used instead. It was realised, however, that the necessary manipulations at temperatures encountered in India led to a grave risk of infecting the handled blood and such measures were abandoned. Concentration of the RBC was effected by some physicians by allowing the blood to sediment for 12 hours prior to transfusion in the inverted bottle, the giving apparatus having previously been inserted.

Examination of fatal results of transfusion showed, however, that death occurred at an early stage, before the circulating volume of the patient had been appreciably augmented, and was, therefore, to be attributed to imperfectly cleaned apparatus, or to pyrogens in the anticoagulant employed (Ellis, 1944). The establishment of base transfusion units, where courses were attended by a large number of medical officers and other ranks, led to a rapid fall in the frequency of tranfusion reactions ; figures given by one physician being a fall from 13 deaths following 30 transfusions given in the earlier period to 2 in 20 transfusions after an improved technique had been adopted. Recovery is reported to have followed careful transfusion in two patients whose initial RBC count was 4,00,000 per c.mm.

In those cases in which anaemia was associated with nutritional diarrhoea (sprue syndrome), control of the diarrhoea by sulphaguanidine and parenteral nicotinic acid therapy led to the rapid response of a previously refractory marrow (Schlesinger, 1944).

The prognosis of cases of grave anaemia was adversely influenced by the presence of diarrhoea and death might occur in a relapse of malaria.

The observation that a refractory macrocytic anaemia would often respond to treatment once a latent malarial infection had become overt during parenteral liver therapy and had been eliminated, led one physician to introduce protein shock therapy by intravenous TAB vaccine, or by massive liver injection, as a routine measure in such cases. In the absence of parasitaemia, however, no haematological response followed anti-malarial treatment combined with liver therapy.

The most important therapeutic advance was undoubtedly the organisation of special anaemia treatment centres, which were first instituted in the Central Command towards the end of 1943, and shortly after in the North Western Army.[4] Finally, nineteen such centres were established in the former command and ten in the latter. Their object was to combine therapy with research, and in respect of the first, much attention was paid to the evolution of satisfactory convalescent diets for Indian patients. Kitchens supervised by trained Women Auxiliary Corps India (WAC(I)) non-commissioned officers (NCOs) or experienced lady voluntary workers, produced special diet of high caloric and vitamin content. The value of this organisation was well proved by

[4] See Appendix B.

the records of 13 such centres, which in 6 months treated 947 patients of whom 83 per cent. were returned to duty.

In general, although cases of average severity slowly recovered under treatment by liver therapy and repeated blood transfusions, the reticulocyte response and rate of build-up of the blood-count was far less favourable than that usually seen in cases of true pernicious anaemia of comparable severity.

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APPENDIX A

Anaemia Cases from Assam—Burma Border.

A large number of anaemia cases (one-fourth and sometimes one-third of the total casualties) were evacuated from Assam and Burma, during World War II. In a Southern Army anaemia centre, Sarwar investigated 500 such cases.

Clinical Manifestations : The signs and symptoms observed in them were so distinctive as to stamp themselves indelibly on the physician's mind. The anaemia, glossitis and diarrhoea (with or without steatorrhoea) were noted in various combinations. They could be divided into five main groups.

Group I : Marked anaemia, macrocytic hyper or orthochromic, RBC count often less than one million, little or no glossitis, and marked diarrhoea.

Group II : Moderate anaemia, RBC count 2·5-3·0 million, marked glossitis and variable diarrhoea, often relapsing in character.

Group III : Slight anaemia, RBC count about 3·5 million, marked glossitis and marked diarrhoea.

Group IV : Slight anaemia, RBC count about 4·0 million, with or without glossitis, marked oedema of ankles, absent ankle and knee jerks, bradycardia, no diarrhoea.

Group V : Marked glossitis but no anaemia or diarrhoea.

TABLE I

Analysis of 500 *anaemia cases according to groups—Assam-Burma border.*

Group	Number of cases	Percentage
I	151	30·2
II	203	40·6
III	81	16·2
IV	6	1·2
V	59	11·8

Stools : In majority of cases (75 per cent.) stools were pale, watery in character, often alternating with periods of constipation. Sometimes stools were normal in colour and consistency for a period varying from 2-5 days. The fat content was normal in about 80 per cent. of the cases. It was only in the very late stage of the disease, that the stools were bulky, offensive and frothy in character with excess of hydrolysed fat. The average figure in such cases varied from 35 to 40 per cent. of the total fat content.

The steatorrhoea had arisen *de novo* in about 18 per cent. of cases, and as a sequel to some form of ill-defined dysenteric symptoms in the rest. It is interesting to compare these figures with those of Manson-Bahr (1943). Of his 200 sprue patients, 40·5 per cent. gave a history of intestinal disorder.

In the Middle East, some of the chronic and relapsing dysentery cases developed stomatitis and steatorrhoea. Many of them, in addition to inadequately treated dysentery gave a history of inadequate diet. This again showed that steatorrhoea probably was the result of vitamin deficiency and links sprue syndrome at least in part with deficiency of vitamins.

Anaemia : The degree of anaemia and type were classified according to mean corpuscular volume (MCV) and MCHC. The normal range of MCV was calculated on the basis of the normal range being 75 to 96 c.μ and a normal range of MCHC varying from 28 to 34 per cent.

TABLE II

Analysis of 500 *cases, according to degree of anaemia.*

Cause	Type	Number of cases	Percentage
Vitamin B ...	Macrocytic, hyperchromic	149	29·8
Iron ...	Microcytic, hypochromic	27	5·4
Iron ...	Microcytic, orthochromic	5	1·0
Dimorphic ...	Macrocytic, orthochromic	236	47·2
Dimorphic ...	Macrocytic, hypochromic	57	11·4
Dimorphic ...	Normocytic, hypochromic	11	2·2
Dimorphic ...	Normocytic, orthochromic	15	3·0

Some interesting points emerged in the investigation of these anaemias. Majority of cases in the group of macrocytic orthochromic anaemia gave a history of malaria. Out of 57 cases of macrocytic hypochromic anaemia, 15 were heavily infected with hookworm, and it seems probable that hookworm was responsible for iron deficiency and hypochromia. The normocytic hypochromic anaemia cases showed dual deficiency; iron deficiency was usually the major one. The blood count improved considerably by iron alone, but by giving diet rich in protein, Vitamin B and liver extract recovery was hastened. No suggestive confirmation of this dual deficiency was obtained by examination of bone marrow.

Glossitis : Tongue changes were variable and often depended on the deficiency which was more predominant. In riboflavin deficiency, in the early stages there was stripping of the fur and the epithelium of the edges and tip, most marked at the tip, leaving these areas smooth, dark red magenta in colour, with flattened papillae. The centre of the tongue in such cases was usually covered with thick white fur. As the case advanced, the tongue was completely stripped of fur and was smooth but not glossy and slightly swollen with lateral indentation caused by teeth. Longitudinal fissuring usually occurred, although at the edges there were a few transverse fissures. The patients also complained of soreness of the tongue. In nicotinic acid deficiency, the tongue was glazed and scarlet in colour with rather shallow

longitudinal fissures. Glossitis was at times also associated with angular stomatitis and cheilosis. This extended backwards into the pharynx giving rise to dysphagia. In 3 cases the picture was one of Plummer Vinson's syndrome. It was more common to see a combination of these deficiencies.

The possible factors responsible for high incidence of such cases in this theatre of the war were :

(i) Inadequate intake of food during the period at home. This was shown by the poor nutritional conditions of many Indian recruits on enlistment.

(ii) Difficulty of supply particularly of meat, fruit and fresh vegetables in jungle warfare due to long lines of communication. The feeding of patrols, literally speaking, has rightly been described as the " quartermaster's nightmares ".

(iii) Service in areas where malaria, dysentery and worm infection (round worms and hookworms) were hyperendemic. The exceptional need for food of high caloric value following such illness could not be met with in forward units.

Intestinal affections led to deficiencies of essential factors by:—

(i) failure of absorption due to intestinal hurry or diminished absorbing surface ;

(ii) failure of the bacteria to grow and synthesise vitamins. This failure was caused either by repeated attacks of diarrhoea, unsuitable alkaline media, or by ingestion of sulphonamide group of drugs (often given irregularly) which reduced the natural flora of the gut thus inhibiting the synthesis of many factors essential to the host, e.g., thiamin members of B_2.

There is another obscure complicated relationship between the gut and vitamins. Sydenstricker, Armstrong, Derrick and Kemp (1936), Bandier (1939) and Petri, Norgaard and Bandier (1940) have " postulated an intrinsic factor produced by the stomach which acts in preventing pellagra. Petri believes that the stomach is necessary for the synthesis of co-enzymes I and II from niacin, of flavoprotein enzymes from riboflavin, and of cocarboxylase from vitamin B_1 ; the latter is in agreement with the suggestion of Laurent and Sinclair (1938) that diminished phosphorylation of vitamin B_1 with failure of cocarboxylase formation may account for gastrogenous polyneuritis. Verzar (1936) believed that the failure to absorb fatty acids and glucose in the sprue syndrome was due to failure of phosphorylation in the intestinal mucosa. Since vitamin deficiencies produce disorders of the gut, and disorders of the gut produce vitamin deficiencies, it is often difficult to decide which is " the cart and which the horse ".

Effects of Low Acidity in the Stomach : Test meal records are available for 150 cases. Of these 82 showed hypochlorhydria, 11 hyperchlorhydria, 19 achlorhydria (not histamine fast), and 38 normal curve. In view of the high incidence of hypochlorhydria, it is possible that this may have some effect in its causation. This hypochlorhydria may

have been constitutional, result of previous intestinal affections or even the result of niacin deficiency itself.

The following possible effects of hypochlorhydria may be mentioned:

(i) Motility of villi is affected, and absorption of vitamin B content of the food decreased. The stagnation and malabsorption leads to flatulence and abdominal discomfort.

(ii) Intestinal flora migrate and multiply.

(iii) The iron metabolism, in relation to bone marrow and haemoglobin, breaks down and produces megalocytic anaemia.

(iv) Porphyrin and serum bilirubin increase and bilirubin excretion decreases.

(v) Following liver damage, bile acids are decreased, which in turn reduce hydrotropy and fat absorption.

(vi) Unresolved fatty acids in the small intestine form insoluble calcium salts ; this affects the bones and then disturbs the whole electrolyte equilibrium.

(vii) Increasing liver dysfunction and excessive porphyrinuria paralyse Meissner's plexus. Disturbance in the motility of villi leads to the break down of cytochrome enzymes and steatorrhoea.

In view of the above it seems probable that there is a clear connection between the aetiology of this nutritional disorder and that of sprue, idiopathic steatorrhoea, and coeliac disease.

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APPENDIX B

Report on Anaemia Centres, Central Command July—December 1944.

This is a consolidated report on 12 centres at garrison hospitals and 3 at base hospitals. These two classes of hospitals catered for two different types of men, those from local sources with a high proportion of recruits in the one and patients evacuated from active theatres of war in the other. Figures from the two have, therefore, been kept separate as they form an interesting comparison.

The report is based on figures received from the officers-in-charge medical divisions/medical specialists of the following hospitals :—

Garrison hospitals

IMH, Ambala
No. 1 Burma General Hospital
CMH Chhindwara
IMH Delhi
CMH Dehra Dun
IMH Jhansi
CMH Kamptee
IMH Lahore
IMH Lucknow
IMH Meerut
IMH Mhow
POW Hospital Yol

Base hospitals

No. 129 IBGH
No. 131 IBGH
No. 135 IBGH

Figures from some of the hospitals and percentages can only be produced in certain sections of this report as the standard method of recording cases of anaemia was only adopted at the end of 1944, and total figures concerning certain aspects of the subject are not available.

NUMBER OF CASES AND ULTIMATE DISPOSAL

Table I gives some idea of the scope of activity of the anaemia centres over a period of 6 months (1 July to 31 December 1944).

TABLE I

Number of anaemia cases and their disposal at the anaemia centres (1 July to 31 December 1944).

Hospitals	Total number	Discharged fit		Invalided		Died		Remaining	
		Total number	Per cent.	Total number	Per cent.	Total number	Per cent.	Total number	Per cent.
Garrison hospitals	1,402	948	68	62	4	34	2	358	26
Base hospitals	607	272	45	60	10	68	11	207	34

The total number under treatment at the base hospitals is certainly an underestimate. Figures received from No. 129 IBGH for instance, only include cases of anaemia with Hb. values of 5 g. per cent. or under, whereas Table VII clearly demonstrates that the largest number of

admissions were in the 5 g. to 7 g. and 7 g. to 9 g. groups (anaemias of lesser severity are, in general, not being considered in this report).

Results obtained in the garrison hospitals are certainly most encouraging ; few cases required invaliding out of the service and the mortality rate was decidedly low.

At the base hospitals the results varied a good deal. The best results were achieved at No. 131 IBGH, where cures were high, mortality comparatively low and it was found unnecessary to invalid many out of the service. On the other hand No. 129 and No. 135 IBGHs had to cope with more frequent convoys and with the bed situation always in mind, were tempted perhaps to invalid and transfer to convalescent depots their cases sooner than was the custom at No. 131 IBGH, who were able to persevere longer with treatment (Table X).

The high mortality and large number invalided at No. 129 IBGH is easily explained by the severe type of anaemia, to which reference has already been made. Comparisons of the results in the three base hospitals are given in Table X.

It is not surprising to find the results at the base hospitals falling short of those obtained at the garrison hospitals. Patients evacuated from forward areas suffered on the whole from severer degrees and types of anaemia, and cases arising in Central India were usually more straightforward and amenable to treatment. Refractory anaemia was more commonly encountered in troops who had been in Assam, the Arakan and Burma, and here nutritional disorders and the metabolic deficiencies arising from intestinal infection were more often the primary cause (Table VI).

ANALYSIS BY UNITS

It has been suggested that the incidence of anaemia is largely determined by the presence in the Indian Army of a large number of ill nourished, poor types of men, particularly exemplified by the enrolled non-combatants or followers. When, however, the proportion of cases among combatants and followers is studied, this explanation is not substantiated.

TABLE II

Proportion of anaemia cases among combatants and followers.

Hospitals	Combatants		Followers	
	Total number	Percentage	Total number	Percentage
10 garrison hospitals ...	762	87	117	13
No. 129 IBGH* ...	...	78	...	22
No. 131 IBGH ...	...	88	...	12
No. 135 IBGH ...	...	88	...	12

*Including pioneer battalions.

The percentage incidence of anaemia in the two classes of men must be considered in connection with the population at risk. Among garrison troops and training depots this varies considerably as the following figures show :—

Percentage of followers in various unit formations

Infantry	...	...	8
Royal Indian Army Service Corps (RIASC)	...	...	20
Indian Army Ordnance Corps (IAOC)	...	...	10
Indian Army Medical Corps (IAMC)	...	...	25
Engineers	...	...	15
Training depots	...	...	10

The average works out at 14·66 per cent. Thus it appears that the incidence of anaemia among garrison units in back areas is distributed evenly among troops and followers in strict proportion to their relative numbers.

In forward areas the proportion of followers affected shows even greater variations :

			Per cent.
Fourteenth Army (permanent establishment)	...	...	58
IV Corps	...	...	9
XXXIII Corps	...	...	9

Indian patients evacuated in convoys to the Central Command came from all the three sources, so it is difficult to obtain a correct figure of the population at risk. It is significant, however, that the proportion of anaemia in troops and followers admitted to two of the base hospitals corresponds almost exactly to the garrison hospital figures. It can be fairly confidently assumed that there is no evidence of a higher incidence of anaemia among followers than among combatant troops.

ANALYSIS BY TOTAL SERVICE

It might be maintained that with the enormous expansion of the Indian Army and the associated lowering of the standard of recruit, a disproportionately high incidence of anaemia would be found in young soldiers of under one year's service. This does not appear to be the case.

TABLE III

Analysis by total service of anaemia cases.

Hospitals		Total service					
		Less than 1 year	1–2 years	2–3 years	3–4 years	4–5 years	Over 5 years
11 garrison hospitals ...	Total	147	172	207	122	57	60
	Per cent.	19	23	27	16	7	8
3 IBGHs (analysis made in a proportion of cases only)	Total	16	79	112	54	33	...
	Per cent.	6	27	38	18	11	...

The incidence seems to be the highest in men who have seen between one to three years service. Other counteracting factors (the better food and healthier life of the army) must therefore be present.

ANALYSIS BY FIELD SERVICE

TABLE IV

Analysis by field service of anaemia cases.

Hospitals		Field service				
		Nil	Less than ½ year	½–1 year	1–2 years	Over 2 years
6 garrison hospitals	Total ...	152	26	40	72	50
	Per cent.	45	7	12	21	15
3 IBGHs (a small number of local cases admitted to two of them)	Total ...	13	29	104	100	62
	Per cent.	4	9	34	33	20

As is to be expected, in back areas among admissions to garrison hospitals, the largest number and highest incidence of anaemia occurred in men who had not been on field service, although the rigours of one to two years in an operational area seem to have had their effect, and in this group there is a sharp rise.

Among troops evacuated from the Fourteenth Army to base hospitals, anaemia, serious enough for evacuation, appeared early—after six months—and the incidence was maintained until the end of two years service, when it began to drop.

EFFECT OF DIET ON INCIDENCE OF ANAEMIA

An analysis was made in eight garrison hospitals and three base hospitals, and the proportion is similar; two-thirds of the cases had arisen in meat eaters and one-third in vegetarians.

TABLE V

Analysis of effect of diet on incidence of anaemia.

Hospitals	Strict vegetarians		Fish/egg eaters		Meat eaters	
	Total	Per cent.	Total	Per cent.	Total	Per cent.
Garrison hospitals	129	22	94	16	362	62
Base hospitals	...	28	...	7	...	65

No estimate can be obtained of the general relative proportion of vegetarians to non-vegetarians among Indian troops and so this analysis was not very informative. Although there are no supporting figures available, it has been the common experience of all centres that some of the most difficult and refractory cases of anaemia to treat had been those occurring in vegetarians.

In considering this aspect of anaemia, it must be remembered that in forward areas, owing to failure of supplies, many normally meat-eating Indian troops become enforced vegetarians over quite long periods.

TYPES OF ANAEMIA

Although attempts were made at all anaemia centres to determine the types of anaemia encountered, with the existing facilities, results were not considered sufficiently accurate to be worth recording. There was ample evidence, however, that all common types of anaemia were present, as well as a high proportion of tropical macrocytic and dimorphic anaemia.

BASIC CAUSES OF ANAEMIA

The basic causes of the anaemia could be found in most cases, chief of these being malaria, dysentery and diarrhoea, ancylostomiasis and nutritional defects. In quite a number, more than one cause was operating and it was difficult to decide which was chiefly to blame.

The principal causes can be tabulated as follows :—

TABLE VI

Principal basic causes of anaemia.

Hospitals	Malaria		Dysentery and diarrhoea		Ancylostomiasis		Nutritional		Others	
	Total	Per cent.	Total	Per cent.	Total	Per cent.	Total	Per cent.	Total	Per cent.
Garrison hospitals	478	52	135	15	200	22	80	9	17	2
Base hospitals	185	51	60	17	49	13	60	17	9	2

Comparison here demonstrates that malaria was easily the most frequent cause in all theatres and that alimentary infections and nutritional defects were more frequent in operational areas. Ancylostomiasis as a basic cause was more commonly found among young garrison troops

and in those under training in depots. Other causes include kala-azar, tuberculosis, syphilis and general septic infections.

DEGREE OF ANAEMIA AT COMMENCEMENT OF TREATMENT

TABLE VII

Degree of anaemia at commencement of treatment.

Hospitals	Haemoglobin (g. per cent.) on admission							
	Below 3		3–5		5–7		7–9	
	Total	Per cent.	Total	Per cent.	Total	Per cent.	Total	Per cent.
Garrison hospitals	17	2	88	12	266	36	366	50
No. 129 IBGH	72	...	98	...	...	...	...	...
No. 131 IBGH	...	4	...	14	...	30	...	52

The relative numbers according to degree of anaemia correspond pretty well in the two classes of hospitals with, however, a slight preponderance of severe anaemia among troops evacuated from the Fourteenth Army as compared to static troops in the Central Command.

RESULTS OF TREATMENT

Considering the degree of anaemia with which the centres had to contend, the results of treatment were certainly encouraging. In the garrison hospital anaemia centres, a series was assessed comprising 971 cases; 870, or about 90 per cent. were discharged fit, and 101, or about 10 per cent. had to be invalided or else died.

The extent to which the centres were successful in bringing the patients' blood picture to normal before discharge is shown in the following table:

TABLE VIII

Results of treatment of anaemia cases with final Hb. values.

Hospitals	Discharged fit			Invalided	Died
	Over 14 g. Hb.	12–14 g. Hb.	Under 12 g. Hb.		
Garrison hospitals ...	176	532	162	68	33

Cases of anaemia were kept for varing periods in different hospitals. This depended to a certain extent on the pressure of other cases requiring treatment and the occupied bed strength.

For example, 101 of the 162 anaemia cases discharged with a Hb. still under 12 g. were from IMH, Lahore, and on analysis, the relative time these patients were kept in that hospital was found to be less than that in any of the other garrison hospital centres.

It was true that anaemia due to ancylostomiasis and malaria often reacted surprisingly quickly to the correct treatment, but many cases required 2-3 months before their blood picture became normal. Here are figures compiled from ten garrison hospitals.

TABLE IX

Stay in hospital and disposal of cases of anaemia.

Period	Fit	Invalided	Died
Under 1 month	304	9	14
1–2 months	342	13	3
2–3 „	122	10	3
3–4 „	20	14	...
4–5 „	6	5	...
5–6 „	5	3	1
Over 6 months	2	...	...
Total	801	54	21

The points to be noticed are that in the majority of cases, 1-3 months in hospital under proper treatment sufficed to bring about cure, that the majority of deaths occurred early and that most of the cases who required over 3 months treatment ultimately had to be invalided out of the army.

On the other hand, in many instances it pays to persevere with treatment. This is particularly well demonstrated in the comparative results obtained in 3 IBGHs (Table X).

No. 131 IBGH was not so pressed for beds, not having to deal with such a large succession of convoys. They were able to keep their anaemia patients in hospital longer, and their ultimate results were, therefore, the best. All those discharged fit had a Hb. over 12 g., a large number over 14 g., and their invaliding and death rate was low. In comparing figures from the three hospitals, it must be borne in mind that all the records from No. 129 IBGH refer only to the severest examples of anaemia, i.e., those with a Hb. of under 5 g. per cent.

Table X

Comparative results obtained in the treatment of anaemia in three base hospitals.

Stay in hospital (months)	Discharged fit			Invalided			Died		
	129 IBGH	131 IBGH	135 IBGH	129 IBGH	131 IBGH	135 IBGH	129 IBGH	131 IBGH	135 IBGH
Under 1 ...	6	1	34	8	...	...	10	...	...
1–2 ...	31	13	36	1	...	...	9	2	7
2–3 ...	22	24	22	14	...	...	11	6	4
3–4 ...	9	20	24	20	1	...	6	1	6
4–5 ...	3	9	8	7	1	1	1	1	...
5–6 ...	2	4	3	7	...	...	3	...	...
Over 6 ...	...	...	...	...	...	...	...	...	1
Total ...	73	71	127	57	2	1	40	10	18
Hb. on discharge fit									
Over 14 g. ...	73	34	3						
12–14 g. ...	...	37	20						
Under 12 g. ...	Nil	Nil	104						

Note:—Figures from No. 129 IBGH include only cases of anaemia with Hb. below 5 g. per cent.

MIXED SOURCE OF CASES

It should be emphasised that quite a number of patients admitted to the garrison hospitals should really have been evacuated from the Fourteenth Army as hospital patients. Instead of this, units had sent them on leave, at the end of which they were brought to the garrison hospital nearest their homes or depots. Some of the worst cases came from such sources. This must be taken into account in studying anaemia as it was encountered in the Central Command garrison hospital centres which was 'coloured' by these patients coming irregularly from the Fourteenth Army. It should be added that steps were taken by the medical authorities of that army to prevent any recurrences.

SIGNS OF AVITAMINOSIS

Avitaminosis was chiefly reported from those centres to which considerable numbers of such cases were admitted, many of them suffering from gross defects of nutrition or chronic diarrhoea in addition to anaemia.

The following three accounts give a picture of the mixed clinical nature and the varying types of vitamin defects observed.

(i) *IMH Ambala—number of cases*—45.

"The commonest evidence of vitamin deficiency was sore tongue and hyperkeratosis of the skin. There was marked inanition in many of the patients, and it may have been due partly to vitamin deficiency, but as many were suffering from chronic bacillary dysentery, this itself might have been the direct cause.

Scaliness and harshness of the skin of the legs and arms were commonly seen, and were frequently associated with dark pigmentation of the face over the malar bones and bridge of the nose. This pigmentation may have originated from erythema, but no cases with erythema were observed on arrival here.

Sore tongues were common, the tongue edges being bright red or the whole surface of the tongue was raw and smooth. Diarrhoea was very common, but it is by no means certain that this is a phenomenon due to vitamin deficiency.

Sigmoidoscopy revealed that many patients were suffering from an apparent mild chronic bacillary infection, although stools culture was usually negative. Few cases showed a frank atrophic rectal mucosa; when they did arise, they were usually moribund and did not respond to any treatment".

(ii) *IMH Meerut—number of cases*—40.

Most patients showed more than one feature of deficiency.

Xerophthalmia	1
Cracked tongue	17
Cracked tongue *plus* atrophy of papillae	6
Atrophy of papillae	22
Pigmented patch on tongue	24
Pigmented papillae (red)	31
Pigmented papillae (black or brown)	24
Loss of lustre on skin of face	24
Apathy	26
Bleeding gums	1
Peripheral neuritis (slight)	1
Pellagroid condition (discoloured hand, feet and face with atrophy of tongue papillae)	13
Diarrhoea	19

(iii) *No.* 1 *Burma General Hospital—number of cases*—14.

"While there is little doubt that many of the patients suffered from multiple vitamin deficiencies, it has been possible to recognise certain fairly well defined types of deficiency. The commonest was nicotinic acid deficiency characterised by soreness of the tongue, some degree of anorexia, retro sternal soreness, flatulent dyspepsia and diarrhoea with bulky undigested stools, together with pigmentation of the skin.

The cases showing the sprue syndrome, mentioned above, are included in this group. Treatment with nicotinic acid produced in some of these cases a manifest riboflavin deficiency characterised by angular stomatitis, painful ulceration of the buccal and palatal mucous

membranes, cheilosis and an angry raw red tongue with fissuring at the edges. There were very rarely any associated skin or scrotal changes. Apart from the cases produced by nicotinic acid therapy, riboflavin deficiency was seen *ab initio* most commonly among patients with 'Manipur diarrhoea' and particularly among a group of patients who underwent semi-starvation at Ukhrul. Among these was a Sikh with such a marked cheilosis that it looked as though the buccal surface of his lower lip had been liberally painted with vermilion coloured lipstick. This patient, in common with others, responded well to treatment with multivitamin tablets. One case of beri-beri was seen which required parenteral thiamin chloride. One patient suffering from nutritional anaemia, had well marked signs of vitamin A deficiency consisting of a horizontal linear opacity in the lower half of the cornea on both sides together with marked pigmentation of the inferior conjunctival fornices. After 2 weeks intensive treatment with adexolin, these signs had quite disappeared, and the patient reported a considerable subjective improvement."

GENERAL COMMENTS ON TREATMENT

(i) *Diet.*

The importance of proper diet in the treatment of anaemia was fully realised by all centres. At each, special diet kitchens were provided and nearly all of them were under the care of WAC (I) or Red Cross supervisors, most of whom had attended a special course.

Anaemia diets were drawn up, conforming more or less to that recommended by Headquarters Central Command.[1] In place of the old two meals a day system, at least four were given, and in cases of severe marasmus, smaller feeds, more frequently, were prescribed.

Vegetarians received particular consideration in the form of extra milk instead of meat. Some could be persuaded to take eggs. Most centres realised that apart from preparing the food in an appetising manner, it was equally important to see that the patients actually received and ate it. The success achieved depended largely on the nursing staff in charge and realising this, as far as possible, matrons co-operated well in picking a good staff for this particular ward.

Most patients could be persuaded to take liver by mouth, either lightly fried or, in the case of vegetarians, flavoured with lime or lemon and disguised as medicine.

In one hospital the 'vegetarian' problem was overcome by adding the freshly extracted liver pulp to the *dal* just before serving.

The steady gain in weight of most patients was satisfactory evidence of the excellence of the diet. In one centre this worked out as an average of 17 lb. from the time of admission to that of discharge.

(ii) *Drugs and Vitamins.*

(a) Iron was generally given as a routine to all patients and the method of preparation of ferrous sulphate with glucose and hydrochloric acid proved satisfactory in preventing the drug's oxidisation.

[1] See Annexure to Appendix B.

(b) Parenteral liver extract was not always in plentiful supply in 1944. It was, therefore, usually reserved for refractory cases and particularly vegetarians. High daily dosage over a short period, rather than spreading smaller injections over longer intervals, appeared to be the method of choice.

(c) Vegemite was readily available, but not all would take the full 2 oz. a day. It was found that the best method was to dissolve it in water and to give it as medicine. In this way most patients could be persuaded to take 1 oz. of the extract daily.

(d) Nicotinic acid, oral and parenteral when available, was reserved for patients exhibiting signs of vitamin B deficiency, associated especially with sprue and chronic diarrhoea. One centre placed greater faith in multivitamin tablets, stating that nicotinic acid alone with a nourishing diet was apt to bring out other vitamin deficiencies.

Vitamin A was seldom required. The general opinion appeared to be that ascorbic acid also had no special benefit in accelerating recovery. One centre, however, gained the impression that vitamin C in high dosage (150 mg. daily for 15 days) was a useful concomitant treatment in anaemia due to those cases of chronic malaria which had not responded favourably to antimalarial therapy.

(iii) *Specific Treatment.*

Cases showing splenomegaly or occasional spikes in an otherwise normal temperature chart, received a full course of mepacrine (previously quinine followed by mepacrine) even in the absence of a positive blood slide. This treatment was also given to any case not reacting favourably to other forms of therapy.

The value of sulphaguanidine in arresting diarrhoea was often found to be a life saving measure. Centres also realised the part played by amoebic infection as a basic cause and took steps to search for it and treat the condition if present. Investigations for ancylostomiasis were carried out as a routine and treated repeatedly if necessary.

(iv) *Blood Transfusion.*

During the period under consideration, 142 patients in the garrison hospital anaemia centres received blood transfusions, several of them many times. Only 18 severe reactions were recorded. In No. 131 and No. 135 IBGHs severe reactions occurred in 9 and 12 per cent. respectively. In No. 129 IBGH, where blood transfusion was a special feature and 558 pints of blood were administered over a period of 6 months, the severe reaction rate was as low as 5 per cent.

ANNEXURE

Diet—Cases of Anaemia

The following diet scale was recommended for the treatment of cases :—

Article	Quantity (oz.)
Atta (or *atta*/rice in desired proportions)	14
Roasted peanut flour (Note 5)	2
Bread	4
Milk (fresh)	36
Eggs	2
Butter	1
Cream	1
Fruit (fresh)...	16
Tomatoes	2
Vegetables (green, leafy)	4
Vegetables (root)	4
Onions	2
Potatoes	2
Mutton (Note 4)	4
Liver juice (raw) (Note 4)	1
Liver (Notes 1 and 4)	8
Ghee	2
Dal	2
Vegemite (Note 2)	2
Sugar	2
Salt	½
Condiments	½
Tea	1/6
Lime juice cordial	as required
Aerated water	as required
Barley water	as required

Caloric value, 5,400 (approx.)

A specimen menu based on the above scale was as follows :—

07·30 hours ...	Tea.
09·00 hours	Eggs, milk, bread and butter.
11·00 hours ...	Liver juice in raw tomato juice, flavoured with worcester sauce, or liver juice with juice of fresh limes and sugar added.
12·30 hours ...	*Chapattis* and/or rice, meat, vegetables and *dal*. Fresh fruit.
14·30 hours ...	Milk.
16·30 hours ...	Tea, bread and butter, fresh fruit-salad and cream.
19·30 hours ...	*Chapattis* and/or rice, liver and vegetables.

NOTES

(1) Liver—This should be fried for not longer than two minutes.

(2) Vegemite—This is best given separately, diluted with water as a bouillon. It can, however, be added to the vegetables, *dal*, etc. Under no circumstances should the vegemite be *cooked with* the food.

(3) *The menu* should be varied by such dishes as *Khichri* (rice and *dal*), *Kheer* (rice and milk) *Halwa* (milk, sugar, *ghee* and *atta*), *Dahi* (milk curd), *Lhassi* (milk curd and sugar), bread and butter pudding, etc.

(4) *Vegetarians*—For those who do not eat meat, an additional 20 oz. of fresh milk or 6 oz. tinned milk should be substituted for the 4 oz. mutton. The liver, however, should be given as a medicine in divided quantities during the day (total 1½ pints). The following recipe (Marriott as quoted by Whitby and Britton, *Disorders of the Blood*, 4th ed., p. 155) enables the whole liver to be taken in a palatable form :

Liver lemonade

Liver is put thrice through a mincer and then through a wire sieve. After sieving a fine pulp remains and half a pound of it should be weighed out and placed in a jug. Add the juice of two lemons and an orange and 1½ pints of water and as much sugar as taste dictates. Before drinking, the fluid should be briskly stirred. It is best served in a red glass. Neither the taste nor the suspension of liver pulp is detectable. If hydrochloric acid is being given, it may be added to the beverage.

(5) *Peanut flour* has a high vitamin B complex content, and should be mixed with the *atta* to make *chapattis* in the proportion of one part peanut flour to seven parts of *atta*.

Any surplus can be incorporated with the *dal*. Peanut flour as supplied will need further grinding in a *chakki*. When peanut flour is not available, 16 oz. *atta*/rice should be drawn.

Patients who are very debilitated must be brought to this scale by graduated feeding. For very sick patients it would be best to begin with a diet of smaller caloric value. The following is suggested, but quantities may have to be reduced at first and increased as soon as patient's digestions have improved :—

Article	Quantity (oz.)
Atta or rice	12
Peanut flour	1
Bread	4
Milk	36
Eggs	2
Fruit (fresh)	12
Vegetables (green, leafy)	6
Onions	1
Ghee	1
Liver juice	1
Liver	8
Dal	2
Butter	1
Jam/honey	1
Vegemite	2
Sugar	2
Tea	1/6
Condiments	½
Salt	½

Caloric value 4,600 (approx.)

Specimen menu—

07·30 hours	...	Tea.
09·00 hours	...	Egg, milk, bread and butter, honey or jam.
10·30 hours	...	Liver juice, vegemite.
11·30 hours	...	*Chapatti* and/or rice, vegetables and *dal*, fruit.
13·30 hours	...	*Khichri*, vegemite.
17·00 hours	...	Eggs, bread and butter, milky tea, fruit.
19·00 hours	...	Rice/*chapatti*, liver extract and vegetables extract or 1½ pints of liver lemonade in divided quantities, throughout the day for vegetarians.

CHAPTER III

Ancylostomiasis

INTRODUCTION

Hookworm infection could be traced on a number of occasions as one of the precipitating causes in producing anaemia which caused considerable number of casualties in the Indian Army during World War II. The high standard of army sanitation and wearing of boots prevented its recurrence to a large extent and since the average life span of the adult worm is generally less than one year,[1] the infection appeared to be self-limiting in nature during service in the army. This was revealed by the diminution in the incidence and degree of hookworm infection with increasing length of service. Hence, the problem of hookworm infection in the Indian Army was largely limited to the recruits as most of the infection dated back to their civilian life.

The incidence among recruits was high and equated with that of the civil population; recruits from areas of high civil incidence being about 80 to 100 per cent. while those from other areas was as low as 10 per cent. or less. As a result of treatment after enlistment, these rates naturally fell very considerably. The overall incidence among trained Indian soldiers was probably in the neighbourhood of 25 per cent. Few of them, however, showed symptoms. The incidence among British troops was negligible.

INCIDENCE AND DISTRIBUTION AMONG CIVIL POPULATION IN INDIA

Ancylostomiasis is widespread throughout India, although the heavy rates were seen in the more moist regions. In the sub-Himalayan division of Northern India from the United Provinces to Assam it was very prevalent, with the incidence increasing from west to east, reaching its maximum in Assam. It was also very common in parts of Central and South India, and in Nepal. The drier parts of India, e.g., the North-West Frontier Province, Rajputana, Sind and Deccan, showed a relatively low incidence. About 60 to 80 per cent. of the population of Bengal, Bihar, Orissa, eastern part of the Central Provinces, some parts of the United Provinces and of the Punjab and also the east coast of Madras were infected, but the average worm load per individual was not large.

Of the two species of hookworm, *Necator americanus* was the prevalent species in South India, Bengal and Burma. *Ancylostoma duodenale* was found to the extent of 5 per cent. in Madras and 20 per cent. in Bengal. In Bihar about equal numbers of the two worms were found, and in the United Provinces and the Punjab, *A. duodenale* was the prevailing species (Maplestone and Mukerji, 1939). A third, *A. braziliensis* was occasionally found. Cases harbouring both *A. duodenale* and *N. americanus* were common, while triple infection was not unknown.

[1] See page 47.

SOURCES OF INFECTION

The chief mode of infection was through the contact of the body with infected soil and, rarely, by ingestion of infected water or food. Recruitment was largely from villages which had no sanitary arrangements. The habit of the sepoy of walking barefoot before he joined the army was mainly responsible for the large number of infected cases. The soldier himself was also a source of infection to his comrades, which, however, owing to the generally good state of army sanitation, was not considerable, unless there was an unfortunate deterioration in the standard of sanitation under conditions of stress.

HOOKWORM INFECTION IN INDIAN ARMY RECRUITS

The expansion of the Indian Army during World War II resulted in an all-out recruitment drive and consequently a large number of Indians of low economic status and poor physique were enrolled. Such men came largely from the South India, Bihar, Orissa and Bengal, i.e., from tracts where the incidence of hookworm infection was high. The nutritional standards of such recruits were low and their diet prior to recuitment was deficient in animal protein and iron. Members of the GHQ (India) Anaemia Investigation Team (1944) observed that one of the main causes of anaemia in Indian troops was a low iron reserve in the recruits, which the ordinary army diet was not able to supplement sufficiently.

Napier, Das Gupta and Majumdar (1941) observed that, in the absence of deficiency of dietary iron, absolute or relative, even a heavy load of hookworms produced no anaemia. Many potential recruits had rice as their staple food which, particularly when polished, was poor in iron. Such persons were on the verge of iron starvation and could not meet in full the demands of blood loss caused by heavy hookworm load. Where iron-protein consumption was adequate, sub-clinical infection usually occurred irrespective of the worm burden; but persons became anaemic if hookworm removed blood more quickly than it could be replaced (Andrews, 1942).

Hynes, Ishaq and Morris (1945) reported that hookworms were present in about 60 per cent. of recruits from Madras and the United Provinces, in about 30 per cent. of nursing sepoys and ambulance sepoys from the Punjab, but in only 12 per cent. of ward servants from the same area. There was marked correlation between hookworm infection and anaemia. With increasing load the degree of anaemia also increased, while men with very light infection had significantly lower haemoglobin levels than the non-infected. On the other hand, the connection between anaemia and hookworms was not constant. One-third of recruits with low haemoglobin concentration (under 11 g./100 c.c.) had no infection, while one-third with moderately heavy infection had over 14 g./100 c.c. Hypochromia, was not more frequent in recruits infected with hookworms than in those who were not infected. It was obvious that hookworm infection was a secondary factor in the

production of anaemia in Indian Army recruits. Anaemias in the recruits considerably improved after a change to the army life and diet. A group of men who were treated daily with 6 grains of ferrous sulphate showed rapid improvement in their health. Hookworms had no measurable influence on the haemoglobin regeneration of the treated or the untreated group, even when their number was moderately heavy.

In a survey of 1,118 Punjabi sepoys, stationed at Rawalpindi during the period September 1943 to January 1945, it was found that 15 per cent. had a haemoglobin concentration less than 12 g./100 c.c., 70 per cent. had between 12 g. and 14 g./100 c.c., while only 14 per cent. had more than 14 g./100 c.c. Ancylostomes could, however, be found in only one-third of the anaemic men. A good correlation between the load of ova and degree of anaemia could be found while those who were only lightly infected showed a significantly lower haemoglobin concentration than the non-infected.

In 1945, the anaemia investigation team working in Mysore State, found that iron-deficiency anaemia with evidence of general malnutrition was the characteristic finding among the South Indian recruits. The general impression gained was that the recruits who entered the army in later years of the war, came of an iron deficient stock, and that this deficiency was accentuated in about one-third cases by ancylostomiasis, chronic malaria and dysentery.

Periodic inspections of recruits at the various training and depot centres at Jubbulpore also revealed that 10 per cent. had anaemia (Hb. 10 to 11 g./100 c.c. or less), which, on admission to hospital, nearly always proved to be due to ancylostomiasis. Undoubtedly the infection rate was much higher than 10 per cent. in the recruits. Mass treatment of recruits from areas where hookworm infection was common was, therefore, considered of great importance. Neglect in this respect in some cases resulted in a large amount of avoidable sickness.

INVESTIGATIONS ON THE INCIDENCE OF HOOKWORM INFECTION

In investigating the causes of a large number of deaths, about eight to ten a day, in an IGH at Manipur Road, post-mortem findings revealed that the patients had often been suffering from multiple diseases such as malaria, dysentery, pneumonia or meningitis, in addition to the fact that they were grossly malnourished and heavily infected with hookworms. Hookworms were present in 89 per cent. of a consecutive series of 100 post-mortem examinations. Shah (1943) concluded that the majority of cases were dying of diseases which were really terminal in malnourished, anaemic, hookworm infected men who had been suffering also from malaria.

In November 1942, a field laboratory carried out stool examinations for detecting the extent of hookworm infection among state labourers in the area. A figure of 53·7 per cent. was obtained, where a high assessment had been made on clinical grounds. During investigations on the efficiency of standard treatment for malaria at Manipur Road, Rogan (1943) examined stools of 385 cases for hookworm. These

included all the Indian and British cases with a haemoglobin below 75 per cent. The saturated saline-floatation method was used and only one specimen of stools was examined in each case. The result of examination is given in Table I :—

TABLE I

Cases of hookworm infection among certain Indian and British troops in Manipur Road 1943.

Troops	Cases examined	Cases of hookworm found positive	Percentage
IORs	348	245	70·4
BORs	37	2	5·4
Positive in *Auxiliary Pioneer Corps troops	...	...	85·3
Positive in other units of the Indian Army	...	...	54·9

Post-mortem examination of a series of 100 consecutive cases revealed the following :—

TABLE II

Results of the post-mortem examination of a series of 100 *consecutive patients.*

Units	Cases examined	Cases of hookworm found positive	Percentage
Indian Army	9	7	77·8
Auxiliary Pioneer Corps ...	15	11	73·3
State labour	76	73†	96·0

Passmore (1944) analysed a series of 200 cases from the anaemia ward at IMH, Calcutta in 1943, and from the anaemia centre at No. 129 IBGH, Lucknow in 1944. Most of these cases had seen service with the Fourteenth Army on the Imphal front or in Arakan. Of this series, 61 patients were classified as hypochromic, with MCHC below 30 per cent. Of these, again 33 were suffering from ancylostomiasis, leaving only 28 or less than 20 per cent. of the total with any evidence of

*Auxiliary Pioneer Corps units consisted largely of South Indians, Bengalis, Biharis and a few Punjabis.

†Two of the three negatives had been de-wormed.

primary iron deficiency. Hookworm ova were found in 68 of the 200 cases by examination of three specimens of stools using the saline-concentration method. In many of these, the degree of infection was slight and in 27 it was considered to be of no significance. Its relative importance in many other cases was problematical. In 46 cases, in which hookworms were found in the stools, haemocrit measurements were done. In 20 (44 per cent.), MCHC values were 25 or less and in these ancylostomiasis was almost certainly an important contributory factor in the causation of anaemia. In 14 (30 per cent.), the MCHC value was 30 or over. In these cases, it could be asserted that the infection was of no significance. In the residual 12 cases (26 per cent.), the MCHC value lay between 25 and 30 and in these instances the importance of the parasite appeared doubtful. Thus, in about one-third of the total number of cases, hookworm ova were found in the stools but only about half of these presented the haematological features of ancylostomiasis.

The comparatively low incidence of hookworm anaemia in the Fourteenth Army troops was in marked contrast to that of many recruiting depots and could possibly be explained by the self-limiting nature of the infection during service in the army. This contention is supported by the following post-mortem evidence. In over 150 post-mortems on cases from the Burma front, a systematic search was made for hookworms. Whilst it was not uncommon to find half a dozen worms, in only two cases more than a dozen worms were found, and in only one of these was the condition considered to be a contributory factor to death. It may be said that whilst ancylostomiasis remained an important cause of anaemia in the Fourteenth Army, its importance was much less in the field than in the base areas.

Vasey (1944) also reported that ancylostomiasis played a major role in the aetiology of anaemia in the cases that were admitted to the anaemia centre at IMH, Jubbulpore. This was not surprising in view of the fact that local incidence of malaria had been low for the preceding two years. In a period of eleven months, 141 cases of anaemia were treated. Hookworm ova could be found in the stools of 52 per cent. cases. In 27 per cent., this was the only ascertainable cause of anaemia ; in 18 per cent. malaria was a complication and in the remaining 7 per cent. the aetiology was so confused that it was impossible to judge the exact part ancylostomiasis was playing.

Minchin (1944) observed that though the work of Rockfeller Commission in India has shown that over 90 per cent. of population of even the driest province was infected with this worm, it should not prove a major problem in serving soldiers provided efficient expulsion of the worms from soldiers was carried out during the training period. The expulsion of a few hookworms or their ova should not be looked upon as the only solution of the man's anaemia problem. With a diet sufficiently rich in iron, a small number of hookworms should do no harm, as it had been shown that even with a heavy infection a high iron diet could more than overcome the resulting anaemia.

Hynes (1944) observed that the Indian Army sepoy's iron intake was certainly not inadequate, for his diet contained at least three times the minimal requirement. He might lose blood by hookworm infection, but it was only rarely that the Indian adult who developed considerable immunity had an infection heavy enough to produce severe anaemia simply by minute haemorrhages. Heavy infection was, however, commoner in severe anaemia cases than in the general population, and might be regarded as the precipitating cause of anaemia in those made especially susceptible by some other unknown factors, possibly dietary.

RELATION OF HOOKWORM INFECTION TO LENGTH OF SERVICE

Vasey (1944) analysed the length of service of the cases of ancylostomiasis seen at the anaemia centre, IMH, Jubbulpore. It was found that the incidence of anaemia due to ancylostomiasis showed a gradual diminution with service, although the number of anaemia cases from other causes remained the same.[2]

ANALYSIS OF SYMPTOMS OF HOOKWORM INFECTION

Shah (1943) observed that cryptic form of the disease in which hookworms though present in the jejunum rarely produced any overt disturbance, comprised the bulk of cases. The victim was often slightly anaemic and due to his lowered resistance was an easy prey to the other diseases, although he remained generally unaware of his condition. It was not until after treatment that he could appreciate the difference in his physical and mental vigour.

The cryptic form of the disease could be easily recognised from the presence of pigmentation of the tongue. In a series of 99 patients, it was present in 28. The pigmentation was generally of a dark-brown colour, appearing as pinpoints over patches of the papillae and though almost always present at the edges, it sometimes extended to the dorsum, and in a few cases, it could be seen under the tongue or even over the palate. In well established forms of the disease the pigmentation tended to disappear and gave place to 'white blotting-paper tongue'. The cryptic condition could also be suspected from the presence of eosinophilia.

The recognition of even well established forms of disease sometimes proved difficult as the individual continued to work unconcerned until puffiness of face or actual oedema of feet occurred. However, the white blotting-paper appearance of tongue, particualry if any residual smudges were present, generally proved sufficiently reliable evidence of the condition. The haematological picture of the disease was that of secondary microcytic anaemia and there was nothing distinctive about it except for the frequent presence of eosinophilia. In general it may be said that in India hookworm anaemia was common and every anaemia case was generally considered as being due to hookworm unless it was proved to be definitely otherwise.

[2] See page 47.

Vasey (1944) made separate analysis of the uncomplicated hookworm cases and of those with both malaria and hookworm infection at the anaemia centre, IMH, Jubbulpore. The uncomplicated cases of ancylostomiasis produced symptoms of gradually increasing weakness with giddiness, dyspnoea and palpitation. Epigastric pain of peptic ulcer type and substernal pain were common. There was occasional diarrhoea but oedema was rare. Very often the recruit had thought himself to be fit until he found that he could not keep up with others during physical training and exercises. The men were usually well nourished, without icterus or glossitis and no particular abnormality was found on examination, except anaemia. The severest case had haemoglobin of 4·5 g./100 c.c. but in the vast majority the figure lay between 7 g. and 10 g. In most of the cases, the cells appeared to be normal in size. The colour index was between 0·9 and 1·1 in 64 per cent. of cases, and hypochromia in 27 per cent. with the lowest colour index of 0·7. Two cases of hyperchromic anaemia (colour index 1·2) were seen, one of them, the severest case admitted to the centre, showed marked anisocytosis and piokilocytosis. Reticulocytes were usually under 1 per cent., the average figure being 2·4 per cent. As the cases recovered, there was a transient increase in reticulocytes to 3 to 4 per cent. These findings support the idea that there was also some depression of the marrow due to a toxin. The only case showing marked hypochromia at any stage was one in which the infection was not satisfactorily eradicated over a period of four months. The colour index declined from 0·8 to 0·5 in this case. The leucocyte count showed no special change except for an almost constant well marked eosinophilia. In 40 per cent. of cases this was in double figures, the highest count being 24 per cent.

HOOKWORM INFECTION COMPLICATED WITH MALARIA

Cases of ancylostomiasis associated with malaria investigated at the anaemia centre, Jubbulpore gave a variable history. They had usually been fairly well until the onset of malaria which, even though promptly treated, often disclosed an unexpected anaemia. It appears as if the patients were able to live in harmony with their infection until malaria became an added complication. They were then unable to recover until the worms were expelled. Severer degrees of anaemia were encountered than in ancylostomiasis alone, haemoglobin levels in the majority being between 5·8 g. and 7·8 g./100 c.c. (lowest 4·5 g.). The type of anaemia, however, was much the same (colour index between 0·9 and 1·1 in 78 per cent. cases). Eosinophilia was present in 26 per cent.

In the investigation initiated by the GHQ on the efficiency of standard treatment of malaria in Assam, Rogan (1943) found that severe anaemia was not found among BORs but was present among IORs in a certain number of cases. The types of anaemia encountered could all be fully accounted for by a varying combination of repeated attacks of malaria, hookworm infection and malnutrition.

The haemoglobin estimations carried out at the end of treatment for malaria failed to demonstrate that any of the four groups of anti-malarial treatment caused anaemia. In fact, in cases free from hookworm, spontaneous regeneration took place to some extent. It would appear that this regeneration was inhibited by the presence of hookworm infection as demonstrated in Table III.

TABLE III

Relationship between types of malaria, hookworm infection and Hb. level in certain cases of Indian and British troops.

Types of malaria	IORs				BORs	
	With hookworm		Without hookworm			
	Cases	Average rise or fall in Hb. per cent.	Cases	Average rise or fall in Hb. per cent.	Cases	Average rise or fall in Hb. per cent.
BT	90	+0·25	40	+1·7	39	+4·4
MT	65	—0·8	36	+1·2	26	+2·0
Mixed	43	—2·6	16	+1·3	9	+0·9
Total	198	...	92	...	74*	...

HOOKWORM INFECTION IN OTHER ARMIES IN THE EASTERN THEATRE

Rogers and Dammin (1946) reported on the incidence of hookworm infection in 50 consecutive cases among the American troops in Assam and North Burma. History of ground itch was obtained in 25 per cent. and of doubtful respiratory symptoms in 70 per cent. They were characterised by gastro-intestinal symptoms of abrupt onset such as anorexia, nausea, vomiting, diarrhoea and cramping epigastric pain after meals. Anaemia was neither marked nor constant. Loss of weight, low-grade fever in a few, and attacks of urticaria were present. Sometimes the cases were characterised by a marked degree of eosinophilia, viz., 70 per cent. The usual figure was, however, 40 per cent. and this persisted for weeks or months. In a series of 2,000 Australian soldiers (1,600 of whom had seen service in New Guinea), 800 were excreting hookworm ova. *A. duodenale* and *N. americanus* were present equally. History of ground itch or creeping eruption was not obtained. Many had symptoms of vague dyspepsia. Variable degree of eosinophilia was present and occult blood appeared in the stools besides ova. Symptoms were uncommon and infection was not apparent till the cases were investigated for some other disease such as relapsing malaria (War Office, 1945).

* Hookworms were found only in two cases.

CONTROL OF ANCYLOSTOMIASIS

Expulsion of Worms from the Infected Persons: Before World War II Indian recruits were treated for hookworms on enlistment and the treatment was repeated if they again showed any symptoms of ancylostomiasis. This had a marked effect in improving health and in preventing the spread of infection within the army. With the expansion of the army since the outbreak of World War II, the magnitude of this task necessitated a modification of policy; and all that was possible was to treat all recruits coming from highly infected areas, and those (from other areas) who showed signs of infection.

Prevention of Ova Gaining Access to Wet Earth: A high standard of sanitation was enforced. Men were compelled to use latrines and the excreta at no stage of its disposal was permitted to come in contact with the superficial layers of the soil. Shallow trench latrines were considered dangerous. In the temporary camps either bore-hole or deep trench latrines were considered desirable. Camp sites were carefully selected and areas suspected of having been previously occupied by the civilian population and the neighbourhood of villages were avoided.

Prevention of Larvae Gaining Access to Man: Sepoys were not allowed to visit any latrine (the ground round which was considered potentially infected) except when wearing boots. Thus the possibility of fresh infection was materially reduced. Even when treatment for ancylostomiasis was not carried out, the army life itself and the boots which the soldier continued to wear, while on leave in his village considerably reduced the chances of re-infection.

TREATMENT

Tetrachlorethylene due to its low toxicity was the drug of choice. When this was not available, carbon tetrachloride was used instead. Treatment was carried out early in the morning before the recruits had any food. Tetrachlorethylene 4 c.c. or carbon tetrachloride 3 c.c. was added to 2 oz. of saturated solution of sodium sulphate and was shaken till the drug was evenly distributed through the mixture. This was administered immediately, before the finely divided droplets of the anthelmintic had time to coalesce into larger drops. No further treatment was necessary except that a dose of saturated solution of sodium sulphate was repeated if the bowels did not open by mid-day.

The addition of 1 c.c. of oil of chenopodium was necessary in the cases which were also infected with roundworms. The two drugs in combination such as tetrachlorethylene and oil of chenopodium, gave better results than either drug alone. Carbon tetrachloride was not given in cases with diseases of the liver and kidneys, respiratory infections and chronic alcoholics. Shah (1943) observed that its use was dangerous when anaemia had advanced to the stage of puffiness and oedema, and in such cases it was considered wise not to take risks with carbon tetrachloride. Carbon tetrachloride was reported to

cause liver damage. Iron helped to improve such cases sufficiently to stand treatment later. A course of iron was considered necessary after routine treatment. Stools were examined every 10 days. If ova continued to appear, a second course of tetrachlorethylene was repeated after a period of three weeks.

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CHAPTER IV

Arsenical Encephalopathy

INTRODUCTION

From 1943 to 1945 an increasing number of cases of encephalopathy following treatment with trivalent arsenicals were reported from military venereal disease treatment centres and military hospitals throughout India. Most of these were Indian soldiers undergoing antisyphilitic treatment, and only occasionally were cases observed following the use of arsenicals in the treatment of diseases other than syphilis. (Singh, 1948 ; Krainer, Black, McGill and Rao, 1948).

The only figures regarding the incidence of this condition in India before World War II refer to a series of cases observed at the General Hospital, Madras. There the incidence was 0·5 per cent. (Rajam and Rao, 1939).

The adviser in venereology, India Command initiated the investigation of this condition and the Pathology Advisory Committee, GHQ, arranged for the co-operation of a team of officers of the Medical Research Organisation, GHQ. The results of their work are contained in a report (Krainer *et al.*, 1948) which forms also the basis of this review. A similar analysis was carried out by Prebble in 1946.

TREATMENT SCHEDULES AHD TECHNIQUE

The incidence of arsenical encephalopathy must be viewed against the background of methods of antisyphilitic treatment. Up to the end of 1942, the standard preparation of arsenic used was sulpharsphenamine. It was administered intramuscularly in weekly doses of 0·3 g. to 0·45 g. concurrently with 0·2 g. of a bismuth preparation. Individual dosage was regulated according to body-weight.

In 1943, neosalvarsan replaced sulpharsphenamine. Patients below 115 lb. body-weight received 0·3 g. per injection. Patients of and above 115 lb. body-weight received alternating 0·3 g. and 0·45 g. per injection. By the end of 1943, the former weekly schedule of injections was generally replaced by bi-weekly injections of NAB intravenously. 4·5 g. of NAB were given as a unit course in bi-weekly injections, while 6 g. had been given in weekly injections.

Syringes were sterilised by boiling on the morning of the injection day. Between injections they were washed in tap water, immersed in alcohol and finally rinsed with distilled water. Needles were sterilised by boiling between injections. Each dose of NAB was separately prepared ; examination of ampoules for discolouration, cracks in the glass and relative insolubility of the preparation was carried out according to the instructions of the adviser in venereology.

INCIDENCE

Of 184 recorded cases of arsenical encephalopathy that occurred between August 1943 and March 1945, 181 were Indian and 3 were British soldiers. According to Prebble (1946) the overall incidence was 1 : 196 in Indian and 1 : 2,430 in British troops. Not only was the incidence in Indian troops very high, but also certain provincial groups were apparently more affected.

TABLE I

Arsenical encephalopathy cases classified according to provincial groups.

Provincial Groups	Number of cases
Madrassis	97
Mahrattas	22
Others	62
Total	181

The incidence of arsenical encephalopathy in two of the larger units, where 40 per cent. of the total number of cases occurred, was considerably higher than the overall incidence.

TABLE II

Comparison of figures for the IMH, Dunkirk and the IMH, Jalahali*
January 1944 to March 45.

Provincial groups	Number of cases under anti-syphilitic therapy	Cases of arsenical encephalopathy	Incidence per cent.
IMH, Dunkirk—			
Madrassis	657	14	2·1
Mahrattas	460	16	3·5
Others	792	7	0·9
Total	1909	37	1·9
IMH, Jalahali—			
Madrassis	1,548	31	2·0
Others	820	8	1·0
Mahrattas (not separately recorded)			
Total	2,368	39	1·6

Krainer *et al.* (1947) based their statistical study on 1,909 cases treated for syphilis with arsenicals at the venereal disease treatment centre of IMH, Dunkirk. These cases received antisyphilitic treatment between January 1944 and March 1945. The team tried to analyse the

*Located in Poona.

influence of different factors on the incidence of arsenical encephalopathy. Tables III to VII illustrate the main points of the analysis.

TABLE III

Incidence of arsenical encephalopathy classified according to frequency of injections.

Frequency of injections	Number of cases under antisyphilitic treatment				Number of arsenical encephalopathy				Incidence per cent.			
	Madrassis	Mahrattas	Others	Total	Madrassis	Mahrattas	Others	Total	Madrassis	Mahrattas	Others	Total
Weekly ...	342	173	380	895	2	2	3	7	0·6	1·2	0·8	0·8
Bi-weekly ...	315	287	412	1,014	12	14	4	30	3·8	4·9	1·0	3·0

FREQUENCY OF INJECTIONS AND INCIDENCE OF ARSENICAL ENCEPHALOPATHY

From Table III the team concluded that the incidence of arsenical encephalopathy in Indian troops treated with weekly injections of NAB is of the same order as the incidence reported in Indian civilians (0·8 per cent. as against 0·5 per cent. recorded in the statistics of the General Hospital, Madras 1939). The cause of the increased incidence in Indian troops, as compared with civilians and observed since the middle of the year 1943, is the treatment of syphilis with bi-weekly injection of NAB. The incidence rate of arsenical encephalopathy in cases treated with bi-weekly injections is about four times higher than with weekly injections (3·0 against 0·8 per cent.).

INCIDENCE ACCORDING TO PROVINCIAL GROUPS

The incidence of arsenical encephalopathy was higher in the two provincial groups with the lower average body-weight.

TABLE IV

Classification of cases under antisyphilitic treatment and cases of arsenical encephalopathy, according to provincial groups and body-weight.

Provincial groups	Number of cases	Weight in lb. Average	Weight in lb. Range
Madrassis under antisyphilitic treatment	657	99	78–148
Madrassis arsenical encephalopathy cases	14	103	95–120
Mahrattas under antisyphilitic treatment	460	103	83–141
Mahrattas arsenical encephalopathy cases	16	92	90–110
Others under antisyphilitic treatment ...	792	108	97–157
Other arsenical encephalopathy cases ...	7	114	100–120

The total number of cases under antisyphilitic treatment in this series (Table IV) was 1,909 including 212 NCOs. Only 3 of these NCOs developed arsenical encephalopathy, the incidence rate of 1·4 per cent. being below the average incidence rate of 1·9 per cent. in this series. No case of arsenical encephalopathy was reported amongst officers or VCOs. One British officer (not in the above series) did develop encephalopathy and subsequently died in the BGH, Alipore.

COMPLICATING DISEASES

Table V shows that attacks of malaria, during or immediately before antisyphilitic treatment, were an important factor in increasing the incidence of arsenical encephalopathy. However this type of cases was only a small fraction (13 cases only) of the total number treated.

The differences in the incidence rates of arsenical encephalopathy in different stages of syphilis (Table VI) are too small for drawing any conclusion.

TABLE V

Malaria and arsenical encephalopathy.

	Number of cases	Incidence of arsenical encephalopathy	Incidence per cent.
Attack of BT malaria during or shortly before antisyphilitic treatment ...	13	4	30·8
Total under antisyphilitic treatment ...	1,909	37	1·9

TABLE VI

The influence of the stage of the syphilitic infection on the incidence of arsenical encephalopathy.

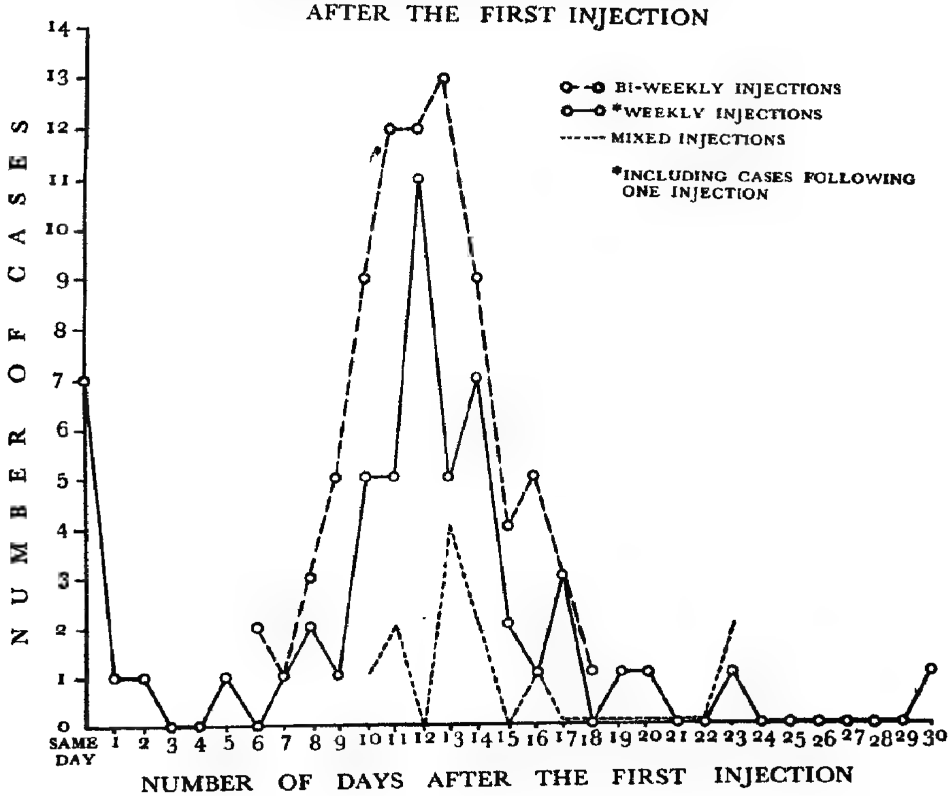
Stage of syphilis	Number of cases under antisyphilitic treatment		Arsenical encephalopathy	
	Weekly	Bi-weekly	Number of cases	Percentage
Seronegative primary ...	166	176	10	2·9
Seropositive primary ...	495	561	15	1·4
Secondary	234	277	12	2·3

TIME OF ONSET OF ARSENICAL ENCEPHALOPATHY

The time of onset of arsenical encephalopathy was independent of the treatment schedule used (Graph I). The peak of incidence was between the eleventh and thirteenth day after the first injection.

Graph I

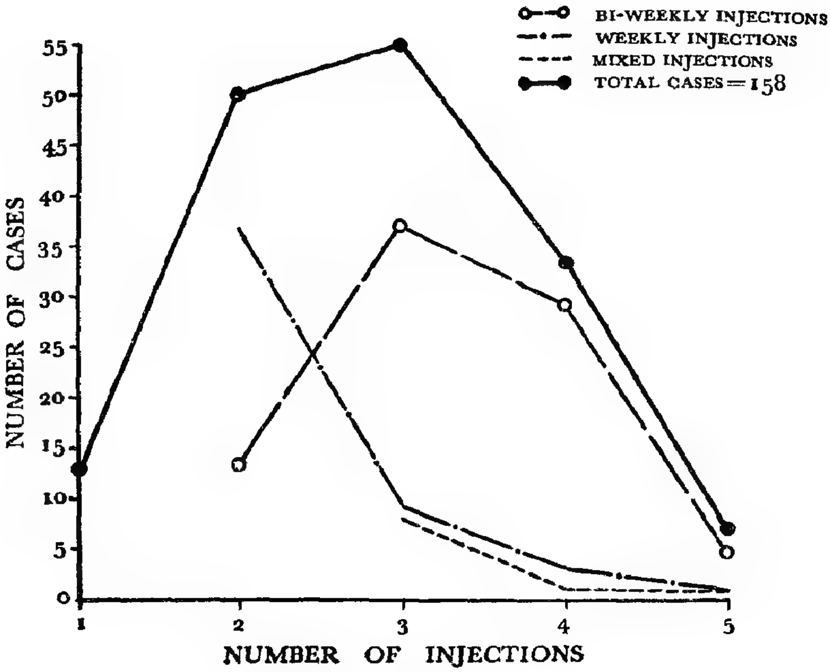
ARSENICAL ENCEPHALOPATHY CLASSIFIED ACCORDING TO THE DAY OF ONSET AFTER THE FIRST INJECTION



In cases treated with weekly injections arsenical encephalopathy appeared most commonly after the second injection. In cases receiving bi-weekly injections arsenical encephalopathy appeared usually after the third or fourth injection of NAB (Graph 2). Fourteen cases of arsenical encephalopathy developed after one injection only whereas none developed after the fifteenth day.

GRAPH 2

ARSENICAL ENCEPHALOPATHY CLASSIFIED ACCORDING TO THE NUMBER OF INJECTIONS ADMINISTERED



THE CLINICAL PICTURE

The majority of cases for antisyphilitic treatment was under hospital care at the time of occurrence of encephalopathy. A unique opportunity was, therefore, available to observe these cases. The team classified the disease into four stages, viz., stage 1—confusion, stage 2—delirium, stage 3—cerebral irritation, and stage 4—coma. As a general rule, two main clinical types were recognisable. In one, the onset was sudden, usually initiated with a 'fit' or sudden loss of consciousness. The majority of such cases rapidly passed into a deepening coma, with increasing pyrexia, terminal pneumonia, and death within 3 or 4 days. The prognosis in such cases was poor, but not invariably so. In the second type, a multiplicity of symptoms heralded the development of the condition, and careful observation was necessary to avoid missing the earliest symptoms. One of the earliest signs was a change in the patient's personality, which was noticed by members of the ward, or the nursing personnel. The patient seldom complained of any disturbance, even on direct questioning, and had little insight into any personality change, although this was sufficient to merit comment from others. This was followed after an interval by various complaints, especially headache, aches and pains, anorexia and nausea, with or without vomiting, thirst, abdominal discomfort, together with a general malaise

and lethargy. After observation of a number of cases, nursing personnel working in the wards and the medical officers were able to pick out cases at the earliest stages, before any complaint was made by the patients themselves. Mental confusion and fear, with sudden and unexplained shivering and sweating, and a tendency to aimless wandering, were the first signs in some cases. A number of patients who developed little else than these signs, recovered. On the other hand, some patients passed gradually through a phase of increasing excitement, delirium, fits and other signs of cerebral irritation, into coma. Signs of excitement never occurred in others and they suddenly became comatose, even while showing signs of general improvement. There were few physical signs which were characteristic. A low grade fever early in the condition was usually present with loss of superficial reflexes in some cases. Pupils showed varying changes, cranial nerve palsies were seen and there was usually weakness of one or more limbs and occasionally actual paresis, in cases with ' fits '. There was complete atonia in the comatose stage. Blood-pressure was within normal limits, except in the terminal stages, when some increase in both systolic and diastolic pressures was present.

The diagnosis presented little difficulty when the condition was established, and the previous history of receiving antisyphilitic therapy with arsenic was known. The earlier stages were difficult to differentiate from a host of other conditions with similar prodromata. A number of cases occurred during summer when heatstroke had to be considered in differential diagnosis. In one instance a patient with heatstroke on admission presented an almost identical clinical picture.

THE CEREBROSPINAL FLUID

The pressure of the cerebrospinal fluid was examined in 10 cases. It ranged between 45 mm. and 190 mm. water, average 87 mm. The cell count ranged from 0 to 40 white cells. The total protein ranged from 70 mg. to 900 mg. per 100 c.c., average 207 mg. It was noted that no case with over 300 mg. protein per 100 c.c. survived.

The Wassermann reaction in the cerebrospinal fluid was negative in 17 cases and positive in 3 cases. Of 16 cases examined by Eapen (1944), the Wassermann reaction was positive in 5 and negative in 11.

SPECIAL EXAMINATIONS

The blood-pressure was within normal limits with an average of 117/73 mm. Hg. The leucocyte count ranged from 2100 to 5000 per c.mm. Albuminuria was present in twelve out of thirty-seven cases. Examination of the fundus in ten cases showed no abnormalities.

FATALITY RATE

Arsenical encephalopathy was responsible for 76·9 per cent. of all fatalities due to antisyphilitic treatment.

TREATMENT OF ARSENICAL ENCEPHALOPATHY

The team had no authority to treat patients on tentative schedules only ; therefore, the standard remedies had to be used in all cases, e.g., venesection, adrenaline and sodium thiosulphate. BAL was not available during most of the time and injectible vitamins of the B group were not readily available. As the fatality-rate shows (Table VII), results of treatment were not encouraging.

TABLE VII

Comparison of mortality figures on account of arsenical encephalopathy and causes other than arsenical encephalopathy.

Complications of antisyphilitic treatment	Number of cases	Fatal cases	Fatality rate per cent.
Arsenical encephalopathy	37	20	54·1
Other than arsenical encephalopathy ...	49	6	12·2

Ransome, Paterson & Gupta (1945) reported a series of five cases which recovered. They attributed their success to nursing in the upright position. Of a series of five cases treated at the IMH, Dunkirk, with continuous oxygen inhalation, four survived. Neither the cases of Ransome *et al.* (1945) nor the cases treated by the team showed cerebrospinal fluid (CSF) proteins above 300 mg. per cent.

PATHOLOGY

Nineteen post-mortem examinations were carried out at IMH, Dunkirk. These cases and material from forty-one cases received by the team from various stations were examined histologically.

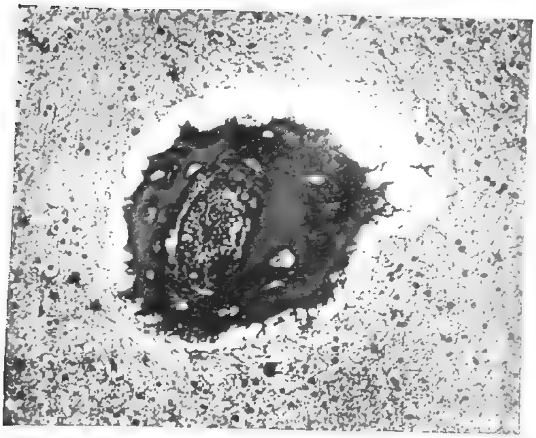
On macroscopical examination only a mild swelling of the brain was noted and there were no signs of greatly increased intracranial pressure. This observation agreed with the CSF findings.

On cut section the brain substance was not ‘ weeping ’ as seen in severe oedema, and haemorrhagic lesions were inconspicuous. There was nothing to characterise the macroscopical picture as ‘ haemorrhagic encephalitis ’.

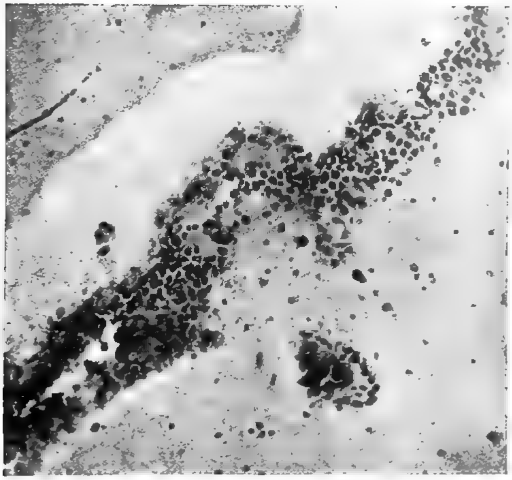
Macroscopical findings in other inner organs were also insignificant. Only the spleen was usually moderately enlarged. The histological examination of various inner organs did not reveal lesions of pathogenic importance. Examination of the liver allowed the exclusion of acute liver cell necrosis. Corresponding to the macroscopical picture, haemorrhage and moderate pulp hyperplasia were seen in the spleen.

PLATE I

ARSENICAL ENCEPHALOPATHY



1. Subcortical white matter; perivascular viscous exudation.



2. Cortex ; meningeal round cell infiltration.

Courtesy—*Journal of Neurology, Neurosurgery and Psychiatry.*

The central nervous system was examined systematically. Venous congestion of the meninges and brain substance, especially of the white matter was conspicuous. Small veins showed marked distention. Small perivascular haemorrhages around veins and arterioles were seen in the white matter and brainstem, but these were only a few. Capillary haemorrhages were practically absent. Damage to endothelial cells could not be ascertained histologically. Occasional round cells were seen perivascularly and so also in the meninges (Plate I). Demyelinating lesions were only seen in two cases. A constant feature was the presence of a viscous exudate (plasma) in the perivascular spaces of occasional arterioles and veins in the brain substance (Plate I). This exudation was independent from hacmorrhagic lesions. Oedema while presen in the white matter was not very conspicuous.

ARSENIC CONTENT OF TISSUES

Determination of arsenic contents was carried out in 9 cases. Tissue digests were assessed by the Gutzeit method. The average values obtained are shown in Table VIII. The figures show absolute and relative high values of arsenic of the brain tissue in cases which died from arsenical encephalopathy if compared with the values obtained in cases which died during antisyphilitic treatment from causes other than arsenical encephalopathy. The comparison was inconclusive as the interval between last injection and fatal outcome was on an average four days in the encephalopathy group and fifteen days in other fatalities.

TABLE VIII

Arsenic contents of tissues—average values.

Diagnosis	Number of cases	Interval between last injection and death in days	Total NAB given in g.	Arsenic contents in mg. per cent.			Arsenic content of brain in per cent. of liver *As* content
				Brain	Liver	Kidney	
Arsenical encephalopathy	6	4	1,35	0·17	0·58	0·66	29·3
Other fatalities during anti-syphilitic treatment ...	3	15	2,95	0·026	0·3	0·43	8·7

DISCUSSION

It has been suggested by Rajam (1949) that the Indian, especially the south Indian, is highly susceptible to arsenic and in particular to complications of arsenical therapy. This is also borne out by this series. It was noted that the incidence of arsenical encephalopathy

was lower in NCOs than in others and this shows that this disease is uncommon in Indian patients in the upper strata. It is also noteworthy that the military hospitals at Jalahali and Dunkirk, where the highest incidence rates were observed, drained a population heavily weighted with recruits and recently enrolled other ranks, the incidence of arsenical encephalopathy as compared to Indian troops in the Middle East (where no fresh recruits were sent for service) was very low. It was, therefore, concluded that the high group incidence is to a great extent a social incidence, the lower income groups which do not enjoy the benefit of a balanced diet being more affected.

Of other factors analysed, two are of sufficient importance to merit consideration. One of them was attacks of malaria ; their effect on the incidence rate of arsenical encephalopathy was very dramatic in cases which were subject to such attacks during or immediately before treatment with NAB. As the number of patients so affected was very small, the influence on the overall incidence was limited. Of the three cases of arsenical encephalopathy examined histologically at the Pathology Department, Armed Forces Medical College, Poona, since 1946, one had a concurrent attack of malaria. It seems, therefore, advisable to withhold arsenical treatment in cases who have or recently had an attack of malaria. One may also consider that in malarious areas instances of arsenical encephalopathy have been interpreted as attacks of cerebral malaria.

The second factor to increase the incidence rate of arsenical encephalopathy was the bi-weekly schedule of treatment of syphilis. Again Mahrattas and Madrassis showed a statistically significant rise in the incidence rate, while Indians from other provincial groups were only little affected. It is, therefore, thought that bi-weekly schedules are not suitable for Indians and especially not for the south Indians.

It appears from the pathological examination that the encephalopathy observed in Indian troops differed from classical haemorrhagic encephalitis by the absence or extreme paucity of haemorrhagic lesions. Demyelinating lesions were also rare. The time of onset, the clinical picture and the findings in the cerebrospinal fluid closely resemble those observed in the classical haemorrhagic condition. The team, therefore, concluded that arsenical encephalopathy in Indian troops is the pathological equivalent of haemorrhagic encephalitis.

It is surprising that identical clinical pictures are produced by haemorrhagic and non-haemorrhagic encephalopathy, in spite of the great difference in the severity of the histological lesions. The team, therefore, concluded that besides the vascular factor a tissue factor is concerned which increases the susceptibility of the nervous parenchyma against the anoxia caused by vascular disturbance.

As the most characteristic lesion in the central nervous system was a viscous exudation of plasma into perivascular spaces indicating an increased permeability of blood vessels, it is assumed that this plasma exudation contributed to the increased protein content of the cerebrospinal fluid.

Little has been added to the understanding of the ultimate cause of the condition. The virus theory has been generally abandoned. Discussion centres round toxicity of arsenicals and hyper-sensitivity caused by arsenicals. The analogy between arsenical encephalopathy and various types of post-infective encephalitis which are interpreted as hyper-sensitivity reactions, e.g., post-vaccinial encephalitis, encephalitis following measles, is striking. One may consider that bi-weekly injections increased the probability of a hyper-sensitive reaction taking place, but the facts available are insufficient to answer definitely the question of causation.

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CHAPTER V

Brucellosis

The term brucellosis embraces both *Br. melitensis* and the *Br. abortus-suis* group. It would have been more satisfactory if the organism responsible could have been isolated in the cases to be described, but as the diagnosis was made by agglutination test alone, it was obviously impossible to differentiate between these two types of infection.

In the Central Command, during World War II, undulant fever was seldom suspected or diagnosed until every other possible disease was excluded either by laboratory investigation or by specific therapeutic trials.

INCIDENCE IN INDIA

There is little in the present medical literature about the incidence of brucellosis in India beyond the statement that it occurs in the Punjab and the north. A small series of cases have also been described in Calcutta and elsewhere. In the army it is not a common infection and only 78 cases were reported among the total hospital admissions during 1939-45. In 1944, the Central Command reported 14 definite cases (Table I). It is quite probable that milder forms of the disease have passed undiagnosed or have been labelled as dengue or typhoid fever.

The infection certainly exists in India and this fact is borne out by figures from one large civil laboratory where agglutination tests against *Br. melitensis* and *Br. abortus* were carried out on a large series of blood-sera sent for Wassermann reaction examination. The percentage giving positive agglutination reactions against the brucella group was quite appreciable and in line with what has been discovered in England and other countries with temperate climates favouring *Br. abortus* infection.

CATTLE INFECTION

Veterinary officers immediately prior to the war became more and more alive to the possibility of abortus infection in cattle in India and in an attempt to lower the incidence of abortion and sterility among their herds, instituted tests, herd segregation and better hygiene in military dairy farms. Preventive inoculation was contemplated but never brought into operation on a large scale, as the war interrupted the whole plan. Figures shown in Tables II, III, and IV give sufficient evidence of the high rate of infection in cows and buffaloes and also indicate that its main source appears to be cross breeding with European stock. During 1944-45 the number of contagious abortions in military dairy farms was 516. No information about *Br. melitensis* in goats in India could be obtained, but the infection does not appear to be extensive.

Table I

Observations on fourteen cases of brucellosis seen in the Central Command during 1944.

Station	Days in Hospital	Type of fever	Number of undulations	Spleen	Liver	White blood cell (WBC) count	Polymorphs	Lymphocytes	Clinical State: Rigors	Sweating	Headache	Furred tongue	Backache	Abdominal symptoms	Bronchitis	Complications: Arthritis	Hepatitis	Broncho pneumonia	Orchitis	Pyelitis	Anaemia	Neuritis	Otitis	Melaena	Meningitis	Deaths	Agglutinations (Figures in brackets day of disease): First	Highest
1. Ferozepore	99	Undulant	4	–	–	5,200	52	46	+	+	+	+			+	+											10,000 (26)	24,000 (38)
2. Moradabad	54	Undulant	2	+	–	7,800	47	48	+			+		+	+												500 (51)	–
3. Ambala	177	Undulant	5	–	–	5,000	32	64			+					+	+								+	Died	28,000 (30)	24,000 (38)
4. Jullundur	53	Undulant	3	–	–	10,000	68	28			+		+		+	+												
5. Agra	56	Single bout	1	–	–	5,400	41	31	+	+		+		+	+												100 (17)	–
6. Fatehgarh	133	Undulant	3	–	+		–		+			+						+									250 (60)	–
7. Hoshiarpur	158	Undulant	3	–	+	5,800	61	34						+	+				+	+							300 (30)	–
8. Hoshiarpur	43	Single bout	1	+	+	3,200	53	41					+	+		+		+			+					Died	250 (23)	5,000 (46)
9. Hoshiarpur	119	Undulant	4	+	+	3,000–8,300			+			+		+	+							+					200 (8)	250 (33)
10. Hoshiarpur	91	Undulant	3	+	–	6,800	70	25				+		+	+	+											250 (18)	–
11. Hoshiarpur	81	Undulant	3	+	–	3,000	59	37			+	+	+														250 (6)	1,000 (54)
12. Hoshiarpur	145	Undulant	3	–	+	4,200	77	20	+			+		+		+						+					50 (13)	1,200 (64)
13. Hoshiarpur	89	Undulant	3	+	–	3,800	60	35			+			+													50 (8)	125 (23)
14. Hoshiarpur	112	Undulant	3	+	–	3,600–6,300	65	31	+					+		+		+			+	+	+	+			2,000 (12)	10,000 (16)

Table II

The percentage of aborters present at a single random observation in the classes of stock indicated.

Class of animal	Number of animals observed	Percentage of aborters
Crossbred stock of 15 military dairy farms ...	1,333	16·0
Country-bred stock of 13 military dairy farms ...	164	7·5
Buffaloes of 15 military dairy farms	1,880	5·0
Indigenous cows, not in contact with crossbred cattle (Northern India)*	4,495	3·5
Buffaloes not in contact with crossbred cattle (Northern India)	895	3·5
Buffaloes in special environments (1 farm around Bombay	281	15·5
Indigenous cows in special environments (3 farms around Bombay)	502	3·5

Table III

Percentage of brucella positive in different areas as observed in military farms (January to June 1944).

Area	Number of animals of contagious abortion examined	Number positive	Percentage positive
Ambala	12	5	42
Bareilly	24	17	71
Ferozepore	39	24	62
Jhansi	10	0	0
Jullundur	171	102	60
Lucknow	83	44	53
Meerut	13	7	54
Poona	142	81	57
Quetta	24	21	88
Ranchi	36	6	17
Shadipur	87	68	78

Table IV

Number of contagious abortions amongst cattle of military farms during the years 1939-45.

Year	Number of cattle (buffaloes and cows)	Number of contagious abortions
1939–40	12,869	40
1940–41	16,120	96
1941–42	23,975	100
1942–43	35,437	91
1943–44	51,136	(Not available)
1944–45	65,637	516

*Northern India is taken to be the territory north of a line drawn from Bombay to Calcutta, excluding Bengal and Assam.

HUMAN INFECTION

During the war attempts were made to increase the supply of milk from military dairy farms but with the expansion of the army, contracts had to be placed on civil sources where cattle supervision was obviously not so good. The whole supply, however, was pooled at the military dairy farm, where one existed in the station, and there the milk was pasteurised. This, if properly carried out, was effective in eradicating any abortus infection and in a survey of some of the dairies in the Central Command, including one station where brucella infection had been observed, the milk pasteurisation was found to be well conducted. The Indian custom of boiling milk before consumption is an added safeguard. Thus it is fair to say that the risk of infection from milk issued through military sources and cookhouses was negligible and the low incidence of the disease was sufficient proof of this. The Indian sepoy in his off-duty time no doubt obtained milk in the bazar, where sterility and adequate heating are obviously often doubtful. In two of the cases, careful questioning led to the admission that the consumption of milk from such sources had taken place prior to the onset of the disease. One patient of this series was a regimental butcher and another a cook, so the infection here possibly arose direct from an infected animal and presumably a goat.

CLINICAL FEATURES AND DIFFERENTIAL DIAGNOSIS

The patient is usually first seen sometime after a bout of fever has begun, for beyond a vague feeling of malaise there are few symptoms at the onset of the disease. Early ambulant cases with quite high temperatures are not uncommon.

Headache, pains in the back and rigors are frequent symptoms. A malarial relapse may complicate the clinical picture, but failure of the usual remedies soon raises doubts as to this infection being solely responsible. Typhoid fever may also be suspected from the furred tongue, the vague alimentary symptoms, the abdominal distension and associated pyrexia. Sweating, cough and signs of pulmonary congestion naturally suggest tuberculosis and this has to be excluded by the usual tests and X-rays. The end of a bout of fever may raise false hopes of recovery and the drug in use at that moment thought to be effective, until a renewed rise of temperature proves that the disease is still active ; in fact by this time the patient is usually beginning to show bad effects of his prolonged illness.

Typhus and kala-azar may also be considered in the differential diagnosis, but their clinical picture differs from that of brucellosis and the bouts of fever in kala-azar are generally much longer. Conclusive evidence can be obtained from the appropriate tests.

Once the disease is well established, arthritis is a frequent complication and this may be mistaken for an infective polyarthritis of a different

nature or even rheumatic fever, but the absence of joint manifestations at an earlier stage would exclude either of these conditions.

By this time the undulant type of fever has become so striking that brucellosis is at last suspected. A leucocyte count showing leucopenia with a relative lymphocytosis is suggestive and agglutination reactions finally establish the diagnosis.

The preceding account is based on the usual approach which is made when an isolated case arises and it is interesting to find that at No. 1 Burma General Hospital, where 8 examples of the condition were encountered in 9 months, the diagnosis was made with less delay as experience of the disease increased.

AGGLUTINATION TEST ON STANDARD BACTERIAL SUSPENSIONS

This has the advantage of becoming positive early in the disease, sometimes as early as 5 days from the clinical onset. Thereafter, it may rise to very high titres and remain positive for a long time—up to 1½ years in one fatal case. In others, however, it becomes negative again as the patient recovers. There are few false positive reactions and in the presence of an undulant fever a positive agglutination in a dilution of 1 in 40 can be taken as pretty conclusive evidence of active brucellosis. The antigen for agglutination tests must be fresh as they become unsuitable after 1-2 months. In all cases isolation of the organism from blood must be attempted. In many cases the titre rises to well over 1 in 250. The highest encountered was 1 in 28,000, but it should be noted that the severity of the infection bears no relation to the titre in which positive agglutination is obtained. The prozonal phenomenon must also be taken into account in carrying out the test, brucellosis being one of those infections in which positive agglutination may only take place in the higher dilutions. Although it is wise to repeat the tests during the course of the disease, a rising titre in which positive agglutination occurs, as in the enteric group, must not always be expected. Brucellosis seems to obey no laws in this respect although a rise is usual, variations in the titre with an unexpected early fall have been encountered. Sometimes a positive agglutination reaction only appears late in the infection and in one case, which ran a typical course, it was negative throughout. This is rare and clearly the diagnosis could only have been made on clinical grounds, but the literature does contain reports of a positive blood culture under the same circumstances.

THE FEVER

The temperature chart reveals certain peculiar features. Occasionally there is only one single bout of fever but usually three or four waves occur before the patient overcomes his infection. With each successive wave the intervening afebrile period tends to increase in length. At first it may be no longer than a day or two or only be represented by the temperature-curve swinging nearer to the normal, but later on there are definite apyrexial phases. The character of the fever may change

during the course of the illness, being remittent at one period and undulant at another. Each bout generally has an abrupt onset and terminates by lysis. Afebrile period may last as long as four to seven weeks, the later waves being less prolonged or at any rate at a lower level. In serious cases the fever may show no undulations and remains constantly at a high level until death occurs.

COMPLICATIONS

Arthritis is the commonest complication and occurred in half the cases. The spine and sacro-iliac joints were favourite sites. Prolonged jaundice due to hepatitis arose in one patient who finally succumbed to meningoencephalitis. Minor degrees of neuritis and a doubtful transient myelitis occurred in three other patients. Orchitis, otitis, melaena, broncho-pneumonia and pyelitis were other occasional complications. Two cases proved fatal. (Table I).

BACTERIOLOGY

In no case, unfortunately, was the specific organism cultured from the blood or urine, owing to war time laboratory difficulties and the late stage at which the disease was usually suspected. The agglutination suspensions provided at first were a combination of *Br. melitensis* and *Br. abortus* and there were thus no means of identifying which of the two was responsible with straight agglutination of the patients serum. The position was not materially altered when later a single abortus antigen was brought into use because of its cross-agglutinating properties. From laboratory tests, it can only be said that this series belonged to the brucella group. Clinically the cases resembled the more severe type of melitensis.

TREATMENT

All forms of treatment were given in these cases including sulphapyridine, sulphathiazole, sulphadiazine, urea stibamine, arsenic injections and immuno-transfusion. None was found to have any influence on the course of the disease. This group of organisms is known to be insensitive to penicillin, hence it was not used. Aureomycin (Debono 1949), now reported to have good effects (Scowen and Garrod, 1948) had not yet been discovered and the same applied to chloramphenicol and terramycin (Knight 1950; Killough, Magill and Smith 1951).

CONCLUSIONS

Brucellosis occurred more commonly in Indian than in British troops in India. The incidence was not high but the diagnosis was rarely made until late in the disease. It is possible that minor degrees of the infection were missed. Patients with prolonged undulant fever, sweating, a furred tongue, vague abdominal symptoms, bronchitis, pain

in the back or joints, should be suspected of having a brucella infection. A moderate leucopenia with a relative lympocytosis is usually present and agglutination tests should be carried out to confirm the diagnosis.

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CHAPTER VI

Cholera

CHOLERA OUTBREAKS

During World War I, there were 2,577 admissions and 610 deaths due to cholera in Mesopotamia. In the *History of the Great War* (1914-18) *Medical Services,* Mitchell refers to the occurrence of the disease in the Russian provinces bordering on Galicia. 22,000 cases with 7,672 deaths were reported in less than four months (20 September to 31 December 1914) amongst the Austro-Hungarian Army in Eastern Galicia. The number rose to 26,000 cases with 15,000 deaths by September 1915. Some troops from Galicia subsequently operated in Serbia and were probably responsible for conveying the infection there leading to an epidemic in 1914. The German Army operating with Austro-Hungarian troops also suffered severely from cholera especially during December 1914 and August 1915. In Turkey during 1916, many cholera epidemics were reported. During the operations on the Tigris for the relief of Kut 377 cases of cholera from the 3rd Lahore, the 7th Meerut and the 13th British Divisions were admitted to the hospitals up to middle of June 1916. Although the British troops were operating in areas where cholera was prevalent, they were affected only in Mesopotamia and Sinai. During the epidemic in the spring of 1916, the British force was unprepared and could not take the necessary precautions to ensure that sterilised drinking water was distributed to the troops (Mitchell and Smith, 1931). The high incidence was, however, generally attributed to lack of water discipline amongst the troops who had been working for long hours in the sand and heat of the desert.

TABLE I

Cholera in Mesopotamia 1916-18.

Year	Admissions	Deaths	Rate per 1,000	
			Admissions	Deaths
1916	1,918	345	11·60	2·09
1917	209	71	0·68	0·23
1918	450	194	1·09	0·47
Total	2,577	610		

In the Indian Armed Forces before World War II, cholera cases were reported both in the barracks and the field from time to time, but no major epidemics amongst them were reported. In the

Annual Report on the Health of the Army in India, cholera always occupied a very low place in the morbidity tables.

During World War II large formations of troops were stationed in the highly endemic areas of Bengal, Bihar, Assam, Orissa and the United Provinces. It is surprising to note that the army as a whole did not show any high incidence of cholera, although during these years several large epidemics had occurred amongst the civilian population. Small outbreaks did occur from one end of the country to the other but due to better understanding of the aetiology, epidemiology, water discipline and value of prophylactic vaccine, cholera ceased to be a major sanitary problem.

Perusal of the figures for cholera given in the Annual Report on the Health of the Army in India shows that morbidity and mortality rate of cholera has been insignificant during this period as compared to the other causes of sickness or death (Table II) :—

TABLE II

Cholera cases in the Army in India 1939-1947.

Year	VCOs and IORs		BORs	
	Admission	Death	Admission	Death
1939	1	—	—	—
1940	1	1	1	1
1941	61	20	25	4
1942	47	11	1	1
1943	154	16	4	—
1944	70	19	8	2
1945	87	20	16	4
1946	100	11	7	—
1947	37	—	6	—

During the retreat from Burma in 1942, cholera broke out amongst civilian refugees at Prome and by the middle of February, 100 deaths from cholera alone were reported in that area. The refugees were being evacuated to Madras and Bengal. Cholera teams consisting of the assistant director of public health and health officers and other auxiliary staff with requisite equipment and cholera vaccine were sent by both these governments. They did valuable work in Akyab and Chittagong. Both preventive and therapeutic work was planned but due to the prevailing circumstances the efforts were directed mainly towards inoculation of personnel and sterilisation of the water supplies. A few cases amongst the troops were reported, but on the whole the retreat from Burma was characterised by the absence of any major outbreak of this disease.

In September 1943, an outbreak of cholera occurred amongst the troops stationed in Mansar Camp near Attock, Rawalpindi District.

The cause of the outbreak remained obscure but in view of the explosive outbreak, the water supply came under suspicion. There were two large units in the station and the water supply was from a common source. As the incidence varied considerably in these two units it was difficult to incriminate the water supplied which was also found to be bacteriologically sound. The discipline in the unit in which practically all cases occurred was not up to a high standard and this unit was using a nearby contaminated stream for bathing and also possibly using the water for drinking purposes.

In 1945, there was a severe cholera epidemic amongst the civilian population of Calcutta. In March 1945, 746 cases were notified and in the first three weeks in April, the figure had reached 468. Twenty-three cases of cholera occurred amongst the residents of Grand Hotel between 20 and 24 April. This hotel was being used as a hostel for military officers and their families. Over 1,000 officers were housed there at the time. There was a civilian staff of approximately 2,200 and out of this number nearly 1,000 were food handlers. All the civilian staff lived outside the hotel in grossly overcrowded and extremely insanitary conditions in the poor quarters of the city. The hotel supplied them with one meal during duty hours, otherwise they consumed food stuffs from cheap stalls or from communal kitchens. There were insufficient latrines and washing facilities were non-existent for the staff. Lieut.-Colonel C. W. Cooper, assistant director of hygiene (ADH) and Lieut.-Colonel S. Narain, assistant director of pathology (ADP) investigated this outbreak. On enquiry it appeared that in the previous week there were three cases of cholera amongst the non-food-handling staff of the hotel. These cases had not been reported to the military authorities. Sanitation of the hotel was fairly good. The water supply was from three deep tube-wells and was chlorinated by an automatic chloronome. Milk was pasteurised and mineral water manufactured in the hotel from chlorinated water. Ice was either made in the hotel or else obtained from a reliable firm. No ice was served in drinks. Washing facilities for crockery and utensils were adequate. Bacteriological examination of water, butter, milk, cream and aerated water were carried out and no *V. cholerae* were isolated from any of these. In brief, there was no apparent sanitary defect. In addition to the routine preventive measures, it was decided to examine all food handlers in order to exclude the sub-clinical cases amongst them. A total of 900 individuals were examined in three days by rectal-swabs method. Enrichment in alkaline peptone water and plating on selective media was the method used for isolation of vibrios. Nineteen individuals were found to be passing true cholera vibrio. None of these individuals appeared to be ill or complained of any intestinal disorder. The vibrios isolated from these cases were identified as Ogawa strain and were antigenically identical with those isolated from the clinical cases. The number of isolations might have been greater if the present day method of taking swabs and direct plating on solid media was used for isolation.

These 19 contact carriers were followed up in order to ascertain how long true cholera vibrios could be isolated from their stool. Three out of the 19 absconded. Five were treated with sulphaguanidine and

became free in 2 days. Repeated examinations of their stools gave negative results. All the rest became free from vibrios in 4-7 days. It was decided to examine on three consecutive days all the new food-handling staff prior to their engagement. Approximately 25 persons were discharged and about the same number was employed daily in this hotel. 2,456 persons from this hotel and certain other units were examined until 18 December 1945 ; but true cholera vibrios were not isolated from any case.

True carrier state as in typhoid and diphtheria does not exist in cholera. It is the 'contact carriers' (sub-clinical cases) which can act as an important source of infection. At the District Laboratory, Calcutta, true cholera vibrios were isolated from mild cases of diarrhoea and dysentery. From the study of this outbreak, it was apparent that in this particular instance the infection was spread by infected food handlers through the medium of water and other drinks. The hotel water, although chlorinated, had no residual chlorine and it is possible for cholera vibrios to remain viable for a period of few minutes even in a dilute solution of alcohol. In alcohol 3 to 5 per cent. vibrios are viable for 15 minutes but non-viable in 30 minutes. In gin dilutes 1 in 2, vibrios are killed in one minute but when diluted 1 in 4, the organisms are viable for 4 minutes and in beer diluted 1 in 3, the vibrios survive for one minute only and are killed in two minutes. Contamination of alcoholic drinks can occur but as vibrios get killed after a certain period, this mode of transmission cannot be given serious consideration (Panja, 1949). The hotel staff had practically no washing facilities and, therefore, it is reasonable to presume that these individuals, while handling food and drink, contaminated them. If the infection had been due to contamination of water supply, the outbreak might have been serious and of an explosive type.

In large civilian institutions, where there is no control over the food handlers, although it is desirable to eliminate sub-clinical cases during an epidemic, examination of stools of all food handlers has no practical value. By examination of the stools one can only certify that a man is free from infection on the day of examination. He may become a sub-clinical case (contact carrier) in the next few days and may never be detected. Such a procedure also gives a false sense of security to the supervising and managing staff. It was, therefore, recommended that in addition to the other preventive measures, the food handlers must be provided adequate latrine accommodation and facilities for cutting nails short and washing hands with soap and hot water. The emphasis was laid more on the hygienic aspect rather than on elimination of carriers.

In May 1946, sporadic cases were also reported amongst the isolated units stationed round about Calcutta. None of these outbreaks caused any anxiety. The experience in these outbreaks was identical with that of the Grand Hotel. 'Contact carriers' or sub-clinical cases were detected amongst the unit personnel during the epidemic period but no isolations were made from food-handling staff during non-epidemic period.

There are no other records of any serious outbreak amongst the troops stationed in Eastern India. The incidence of cholera on the Indo-Burma front during the war was as follows :—

TABLE III

Incidence of Cholera in Burma and SEAC (excluding Ceylon).

Categories of troops	1942		1943		1944		1945	
	Actual	Rate per 1,000	Actual	Rate per 1,000	Actual	Rate per 1,000	Actual	Rate per 1,000
Indian troops ...	75	0·52	265	0·70	64	0·15	65	0·16
British troops ...	22	0·44	31	0·45	4	0·04	7	0·08
West African other ranks	...	...	...	...	5	0·13	2	0·05
All forces ...	97	0·50	296	0·66	73	0·14	74	0·13

A series of investigations on cholera were carried out during the war. The position on the cessation of hostilities is discussed below.

AETIOLOGY

Throughout the greater part of the Nineteenth Century, there was a great controversy regarding the aetiology of cholera. The general view held was that the cause of cholera was of uncertain origin and that certain climatic conditions were essential for its spread. Generally insanitary conditions were recognised as a contributory factor but the theory of transmission by air was most favoured. In 1883, Koch discovered the vibrio in the stools of cholera patients in Egypt and later he came to India where at the Medical College, Calcutta, he confirmed and found the same vibrio in the stools of cholera patients. Serology of cholera was not understood for a fairly long time and the real progress in the epidemiological study was held up. In this confused atmosphere the Health Organisation of the League of Nations appointed a Cholera Commission and the Indian Research Fund Association decided to devote a considerable sum to cholera investigations. The Office *Internationale d'Hygiene Publique* considered that it was advisable to re-investigate the subject of serological diagnosis of *V. cholerae* and that it was necessary that the term 'agglutinability' as applied to the causative organism should be formulated in such a manner as to ensure that all laboratories should interpret it in the same way. The Medical Research Council in 1934 put forward a proposal for undertaking the preparation, not of standard O serum but of a standard O antigen *V. cholerae.* It was proposed to prepare this in a dry form which would be stable. Such an antigen, if satisfactorily produced, was expected to constitute a reagent by means of which it would be possible to raise

agglutinating sera of similar character in any laboratory. In the preparation of dry antigen, the selection of the strain or strains to be used was a point of primary importance. This was studied by Gardner in association with Venkatraman (1935) and they classified cholera strains into six different groups according to their O antigen but many strains still remain unclassified. Cholerogenic vibrios were placed in Gardner and Venkatraman O Group 1 (with sub-type Inaba and Ogawa). Extensive field trials on sera raised by the use of standard dry antigen in endemic and epidemic areas on recently isolated strains were carried out in India in order to assign them in a definite epidemiological significance. This work in India eventually led to considerable clarification of the position regarding the aetiology and serology of the disease (Taylor, 1941).

Typical *V. cholerae* is the vibrio which agglutinates with pure O serum produced by use of dried O antigen of O sub-group 1 of Gardner and Venkatraman. On the other hand H antigen may be possessed by many vibrios in common with *V. cholerae* so that agglutinability with Inaba HO serum is not satisfactory for the identification of cholera vibrios. Due to the lack of knowldege of the true antigenic structure of *V. cholerae*, classification prior to 1935 was extremely difficult. Epidemiological problems became confusing as vibrios other than cholerogenic vibrios could be isolated from surface waters, stools of cholera and non-cholera patients and other sources. Taylor and Ahuja (1938) made extensive observations and came to the conclusion that inagglutinable vibrios were almost always present in unprotected wells and rivers in areas of Northern India where cholera is not endemic and their presence is in no way related to contamination from cholera sources. These authors also state that it is obvious that with this almost universal distribution of vibrios in water, including water which may be used for drinking purposes, vibrios must always obtain entrance to the intestinal tract of those using the water and the appearance of those vibrios in stools of healthy individual or in cholera cases is to be expected.

Tomb and Maitra (quoted by Bonne, 1948) concluded that agglutinable vibrios from cholera patients become inagglutinable in water tanks between 12 to 20 hours.

Pasricha, DeMonte, Chatterjee and Mian (1939) noted that vibrios isolated from different samples of water from flies and cockroaches were all inagglutinable with Inaba O serum.

ISOLATION AND IDENTIFICATION OF *V. CHOLERAE*

Isolation of *V. cholerae* may be very easy or remarkably difficult depending upon whether one is dealing with a frank case of cholera in its acute stage during an epidemic or with a convalescent or a contact after the subsidence of epidemic. It is, therefore, very important that in order to establish a correct diagnosis standardised cultural, biochemical, chemical and serological technique should be adopted. Ahuja,

Krishnan, Pandit and Venkatraman (1951) have recommended the following procedure for isolation and identification :—

(i) *Collection of Specimen :* The isolation of *V. cholerae* from a suspected case is most readily made from a specimen of freshly passed stool or one obtained by the insertion of rectal swab beyond the anal sphincter. If facilities for adequate bacteriological examination are available locally, the material should be plated directly on a suitable solid medium. If, however, a delay of some hours is anticipated, or if the specimen has to be sent to a distant laboratory by post, a small portion of the stool should be placed in a bottle containing 10 c.c. of a preserving medium of potassium chloride, boric acid, sodium hydroxide and sea salt solution. In the case of examination of convalescents or contacts, it is more satisfactory to secure a specimen stool about 1 g. to 3 g. and add to the preserving medium.

Direct microscopic examination of a dried film and from washed flakes of mucus present in rice-water stools of clinical cases of cholera, reveals the presence of numerous actively motile organisms which form the basis of a provisional diagnosis of cholera. Too much reliance cannot, however, be placed on this as non-cholerogenic vibrios abound in all natural water sources in the plains of India and are to be found mixed with specimens of stools. Direct plating of fresh material or material held in preserving medium is preferred to plating after enrichment.

Either plates of alkaline nutrient agar or a differential medium such as Aronson's medium or a modified Wilson and Riley's solid medium may be used. The superiority of the results obtained with direct plating over those obtained with preliminary enrichment has been pointed out by Pandit (1951).

For the examination of stools of convalescents and contacts, a preliminary enrichment is necessary. Read's modification of Wilson and Blair's fluid enrichment medium has been most useful. This method is particularly valuable when vibrios are very scanty in the stool.

Typical colonies of *V. cholerae* should be tested by slide agglutination against a suitable dilution (1 in 50 to 1 in 100) of cholera agglutinating serum containing both Inaba and Ogawa agglutinin.

During an epidemic the provisional diagnosis of cholera can be given if slide agglutination is positive. The result should, however, be confirmed by detailed biochemical and serological tests.

(ii) *Serological Identification :* For serological identification suspension of about 18 to 24 hours growth on nutrient agar in 0·85 per cent. salt solution containing 0·2 per cent. formalin and adjusted to contain approximately 2,000 million organism per c.c. should be used. Agglutination test should be carried out in a water-bath at 52° C. with Inaba and Ogawa O agglutinative serum.

A 24-hour culture, isotonic in Douglas broth should be utilised for haemolysis test by adding 1 c.c. of culture to 1 c.c. of 5 per cent. suspension of sheep or goats cells which are not fragile in 0·65 per cent., saline. The result should be read after 2 hours incubation at 37° C. followed by overnight incubation in the cold room.

Standard test for haemolysis is the only means of differentiating El Tor vibrios from true cholera vibrios.

The position of El Tor vibrio is still obscure. In India, it has not been isolated from any clinical case of cholera, although in Celebes certain outbreaks have been ascribed to this organism. Venkatraman, Krishnaswami and Ramakrishnan (1941) in India have isolated this organism from natural and other sources.

CHOLERA TOXIN

Clinical manifestations of cholera are presumably caused by an endo-toxin produced by the organism in the intestine. The organism does not invade the blood stream.

DeMonte and Gupta (1938) failed to isolate cholera vibrio from the blood of 26 cholera patients but Pasricha *et al.* (quoted by Bonne, 1948) isolated it from the liver of one patient. Chatterji and Malik (1938) could not isolate it from the urine of 122 patients. Most of the clinical manifestations are probably due to the local action of cholera toxin, although some immunity response is detectable in the blood stream itself. The chemical nature of cholera toxin is still obscure as until now it has not been possible to isolate it in its pure form. Studies of chemical constitution of *V. cholerae* shows that it is a complex body, containing more than one fraction, i.e., protein, polysaccharide and phospholipid. The recent work of Burrows (1944) has shown that the phospholipid fraction is probably the endo-toxin. Burnet and Stone (1947) have shown that filtrates of cholera vibrios contain enzymes which can cause desquamation of the intestinal mucosa of guinea-pigs. One of the enzymes has been identified as a mucinase.

Srivastava, Gurkirpal Singh and Ahuja (1948) isolated polysaccharide fraction from *V. cholerae* by phenol methods and have shown that it is responsible for conferring immunity against cholera infection in experimental animals. Immunity so formed is of a high order and infected animals are able to withstand a test of infection of at least 200 lethal challenge doses. Protection following polysaccharide vaccination compares favourably with that conferred by anti-cholera vaccination.

It is probable that the cholera toxin consists of more than one fraction and each one of these possibly has a distinct role in the causation of clinical cholera. In the present state of our knowledge, it is difficult to state whether the so called endo-toxin of *V. cholerae* is a good antigen or not. It is not clear whether this toxin is capable of producing circulating antibodies which can act directly by neutralising the lethal effects of the endo-toxin, or one capable of producing sessile antibodies only which can enhance the local tissue resistance and prevent clinical cholera. Active preparations of cholera endo-toxin are lethal to experimental animals but no toxin has yet been prepared which is an efficient producer of protective antibodies. A large scale and thorough study of the protective value of anti-cholera vaccination by Adiseshan, Pandit and Venkatraman (1947) have shown that anti-cholera vaccination confers significant protection against incidence of cholera but not against death from cholera. This may be due to the enhancement of local

tissue resistance by the vaccine due to sessile antibodies being produced in the intestinal mucosa and conferring protection against the attack of the disease. The non-protection against death is probably due to non-production of protective circulating antibodies against the absorbed lethal fraction of endo-toxin. There are many gaps in the knowledge of cholera immunity mechanism, and this has held up the development of effective immunising agent for the prevention of cholera.

EPIDEMIOLOGY

Role of Carriers in the Spread of Cholera : Results of inquiries under Indian Research Fund Association on this subject undertaken on different occasions in an endemic area in Bengal are summarised as follows:—

> " The cholera convalescents and the contact carriers in most cases are free from the vibrio after five days from onset of the attack or contact with a connected case. In a few cases longer persistence may occur, the maximum periods found for the two classes being 13 and 9 days respectively. Persistence of *V. cholerae* in water is apparently longer, the maximum period found being 16 days by the technique used.
>
> The cholera vibrios have not been isolated except in immediate relationship to the cholera case ".

The importance of germ carriers in the transmission of cholera varies considerably according to the type of carriers, i.e., sub-clinical, convalescents and healthy carriers.

Sub-clinical cases and cases at the end of the incubation period constitute the most important agents in the transmission of cholera.

Convalescents can excrete vibrios up to a period of 15 days and this period in exceptional cases can be a month or even more. However, all observers agree that convalescents do not play a significant part in the transmission of the disease. This view is based on the findings that at the end of the disease and during convalescence an increasing proportion of the vibrios excreted by the patient are in the process of roughening or are entirely rough. Transformation from the smooth to the rough state corresponds to a loss of pathogenicity of the organism. No reversion from the fully rough to the smooth form has so far been observed. Healthy germ carriers are usually to be found amongst contacts of confirmed cases. Their number decreases with the epidemic and they rapidly disappear after its end. They play only a minor part in the transmission of the disease.

It can, therefore, be reasonably stated that actual cases of cholera (including sub-clinical) need alone be considered as positively dangerous from the point of view of the spread of the disease and international quarantine action seems to be justified only against them. From all available evidence it is apparent that the role of cholera carriers, convalescent or healthy, is so insignificant, and the chances of production of carriers even among those living in cholera endemic areas are so small that measures to detect and deal with such carriers appear to be

meaningless for controlling an epidemic or international spread of the disease.

Intensive studies have indicated that a cholera case is the only source of infection. There is no animal reservoir. The present view is that during non-epidemic period the infection is maintained by sub-clinical cases. There is no such thing as carriers of cholera in the sense that is applied to typhoid carriers. The patient passes cholera vibrio for a few days only.

In order to explain the epidemiology, attempts have been made to define endemic areas. Criteria for endemicity have been laid down and by statistical studies Lal, Raja, Satya Swaroop and Basak (1941) have defined certain areas in Bengal, Assam, Madras, Bihar, etc., which conform to the definition of the endemic area.

Satya Swaroop, Raja, Lal and Basak (1941) have made an exhaustive statistical study of the endemicity of this disease and made the following observations :—

(i) that the endemicity may be related to the environment and not wholly to the human being.

(ii) being a water-borne disease, low lying areas with excessive amount of water are associated with high incidence.

Maintenance of infection in an endemic area has always interested bacteriologists and epidemiologists. Although the present opinion is that vibrios cannot survive in natural water for more than 24 hours, yet the role of sub-clinical and missed cases is of greater relevance. However, workers in India have shown that in favourable conditions, like high organic content, alkaline salts, vibrio can survive in water not only for days or weeks but for months.

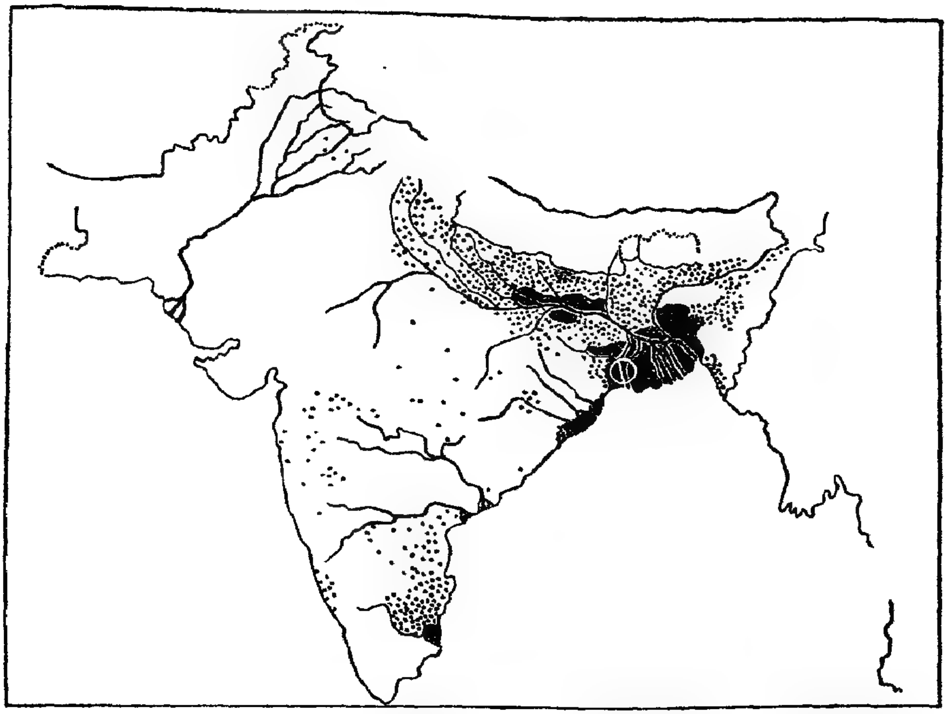
From the epidemiological point of view, it is very important to know whether the infection is maintained in the environment or host or in both. There are certain well defined areas where cholera is never absent at any time of the year. Epidemics always start from these areas and so far as we know the only mode of spread is a case of cholera. Seasonal collection of large groups of people especially in summer and autumn for fairs and festivals are largely responsible for starting epidemics in Bihar, Orissa, the United Provinces and other places in India.

CLIMATE

Cholera is associated with high humidity and relatively high temperatures but for epidemic spread humidity appears to be a more important factor than temperature.

The study of epidemiological aspect is very important not only to control but, if possible, also to eradicate cholera from endemic areas. Eradication of cholera from an endemic area will automatically control the epidemic spread of the disease.

CHOLERA ENDEMICITY IN INDIA IN RELATION TO THE RIVER SYSTEM



Courtesy The World Health Organisation.

PATHOLOGY

The ingested vibrios reach the intestine where bacterial multiplication occurs rapidly. The gut wall is irritated by the toxin of the *V. cholerae*. The nature of this toxin is not yet clear. The gut wall responds to the irritation of the toxin with a profuse outpouring of the fluid causing profound dehydration and severe shock. Whether the death is due to shock and physiological upset or toxin has not as yet been explained. It is also difficult to say whether death results from the toxin causing irritation or from its absorption into the blood stream.

Bannerjee (1939) has described the post-mortem appearance and histological picture in fatal cases of cholera. He considers that destruction of intestinal epithelium may be the cause of draining of body fluids and salts. In the 'vaso-motor failure' type of disease allergic process may play a part in the profuse evacuation. A 'renal failure type' is recognised in which hypochloraemia may be more important than simple dehydration.

Bone-marrow in fatal cases of cholera shows great dilatation of capillaries and sinusoids. This change is found in many organs. This dilatation, it is suggested, may partially explain the collapse which is

a feature of cholera. The pathological changes in the kidney are not inflammatory and most of the congestion as ascribed to histamine like substance and uraemia is thought to be due to low blood-pressure.

Pasricha and Malik (1940) studied the blood in cases of acute cholera. There is an increase in cell volume, haemoglobin percentage, urea and non-protein nitrogen, total plasma proteins, fibrin, globulin, organic phosphates and glucose concentration. These are mostly the effects of dehydration.

Chatterji and Sarkar (1941) also give results of blood investigations in cholera. They found an increase of potassium inorganic phosphates, and of urea and non-protein nitrogen with a decrease of sodium, calcium, chlorides and blood sugar. These authors point out that one of the most important features is acidosis which is also found in shock.

Ghosh and Chakraborty (1940) have investigated the chemical constituents of fresh stools in cholera which are highly alkaline. Elimination of alkaline base and chlorides leads to acidosis and disturbs the osmotic balance and it is thought that the latter may have some bearing upon renal function resulting in the suppression of urine. Marriott (1947) has greatly clarified the symptomatology of cholera by describing the effects of depletion of water and salt respectively.

TREATMENT

Rogers while working in Calcutta introduced the treatment of cases with saline which reduced the mortality rate to a great extent. Attempts have always been made to introduce bacteriocidal and antitoxic agents in addition to saline treatment. Bacteriophage, sulphonamides and antibiotics came into the field but it appears that the treatment of dehydration is more important than that of intoxication. Conflicting claims were produced regarding the efficacy of the sulpha group of drugs for the treatment of cholera.

Chopra, DeMonte, Gupta and Chatterjee (1941) used sulphaguanidine for the treatment in a series of 218 patients and the case mortality was 3·21 per cent. as against 6·3 per cent. who received saline treatment only.

Beneficial effects with sulphonamide therapy (mainly sulphaguanidine) were also reported by Amberson (1945), and Gupta, Chatterjee, Paul and Ghose (1945), and in the *Report of the Scientific Advisory Board* of the Indian Research Fund Association for the year 1944.

Pasricha, Panja and Paul (1940) compared five methods of treatment in Calcutta in comparable group of patients. Bacteriophage apparently gave better results than calomel, potassium permanganate, essential oils or M and B 693 and these authors advised its adoption as a routine.

Bhatnagar, Fernandes, de Sa and Divekar (1948) wrote most favourably of their experience with the compound sulphathiazole with formalin which they used in 85 patients with only 3 deaths. The

patients were treated in their own homes and no other treatment was given.

Venkatraman (1948) treated 138 cases in which diagnosis was established by the isolation of *V. cholerae.* Seventy-five cases were treated on Formal Cibozol and 63 under routine hospital treatment. The result obtained with this drug in Madras seemed to indicate that in cases receiving saline and other supportive treatment, the administration of this drug does not give more benefit than any other sulpha drug previously tried and given up.

It is not easy to reconcile these conflicting reports but it may be stated that when the hospital cases are treated with saline transfusion and other resuscitative measures, the administration of sulpha group of drugs and antibiotics does not reduce the mortality significantly.

It may, however, be stated that the disease in an endemic area like Calcutta where most of the work was done is of a comparatively mild character clinically and also the mortality rate is low. Results of therapeutic trials carried out in this area cannot be compared with those obtained in other epidemic areas.

Panja and Ghosh (1943) reported that atebrin also can produce good therapeutic results.

To summarise, it may be stated that the treatment of cholera consists in restoring water, salt and alkaline balance in the body. The blood-volume and proteins must also be brought up to normal level. Bacteriocidal and antitoxic agents will play a secondary role till the immuno-chemistry of cholera is better understood.

PREVENTION

With the present state of our knowledge, prevention of cholera in a controlled community is not very difficult. Our aim, however, should not be to control cholera but to eradicate it. Attempts are being made for a thorough study of cholera in endemic areas. Better knowledge of transmission and survival of the vibrio during a period of low incidence will help the campaign for the total eradication of the disease. With the eradication of the disease from an endemic area the dangers of epidemics will disappear.

VACCINE CHOLERA

For many years cholera vaccine has been extensively used in India and elsewhere as a personal prophylactic specially when cholera epidemics were imminent or in progress. In most of the observations, there was some doubt about the effective exposure to the disease being identical in the case of inoculated and uninoculated populations. Serological types of cholera vibrios had not been sufficiently recognised before 1935 and all studies were carried out with vaccine containing vibrios whose types could not be stated with certainty.

Adiseshan *et al.* (1947) carried out a statistical evaluation of the data collected during and after the epidemic of cholera in several

affected areas in Madras Province in 1942-43. The investigation was carried out on the experience of 1·18 million inoculated persons in 2,350 villages in eleven districts and the vaccine used contained both Inaba and Ogawa sub-types of *V. cholerae* of which one dose containing 8,000 million organisms was administered. The case incidence rates in inoculated and uninoculated represented a ratio of 1 : 10. In another analysis of a later outbreak the incidence in uninoculated was found to be 14·23 times greater than in the protected groups. Their analysis provided proof that inoculation affords a definite degree of protection against an attack of cholera. It was also found that the benefit of inoculation to uninoculated person if he contracted cholera was negligible, i.e., there was no significant fall in mortality rate in the inoculated group. The immunity, induced by a single dose of vaccine while adequate in greater majority of cases to arrest the onset of symptoms, breaks down in the presence of massive infection. It was also concluded that judged by the incidence of cholera in the inoculated personnel in that investigation, immunity first manifested itself on the fourth day after inoculation and reached an effective level after 8 days. Evidence was also presented that the immunity conferred by anti-cholera inoculation lasts for a minimum period of 6 months and probably remains effective up to 12 months. Herd immunity played an important part in preventing multiple outbreaks in a locality during an epidemic. If, during the first outbreak 50 per cent. or more of the population at risk, is inoculated, the chances of subsequent outbreaks were greatly reduced. The conclusions arrived at were based on the analysis of the field data using a village or a hamlet as a unit to define the population 'at risk'.

Chandra Sekar (1947) selected a part of a village as a unit for statistical assessment so that the population 'at risk' could be reasonably considered to have been exposed to the same amount of risk. As a result of his study it was concluded that the attack rate in the 'not inoculated' population was 2·4 times that in the inoculated population.

There is adequate scientific evidence in support of the value of inoculation as a prophylactic measure. It is, therefore, very important that vaccine used for such purposes must have high immunising property. The vaccine used in India is manufactured by the Central Research Institute, Kasauli, Haffkine Institute, Bombay, and King Institute, Guindy. Due to shortage of agar in India during the war Sokhey and Habbu (1950) prepared a cholera vaccine in liquid medium containing acid hydrolysate of casein. The potency of vaccine obtained by the new method is defined by the results of biological assay on the mouse as it was found that protective power of a strain was linked with its virulence. It has also been claimed that the casein hydrolysate vaccine has a much higher protective power than other cholera vaccines used in India in 1945.

From the above discussion it is apparent that although the value of prophylactic inoculation is well established, modern preventive hygienic measures cannot be relegated to a secondary place. It has

been shown that immunity even in inoculated persons can break down if large number of bacteria are ingested. The chances of survival then in the inoculated are no better than those of uninoculated.

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CHAPTER VII

Dehydration

INTRODUCTION

At the end of World War I, dehydration was generally considered purely in terms of water depletion. The role of salt depletion in relation to dehydration was imperfectly understood. The first to apply continuous salinisation as a therapeutic measure, in tropical countries was Rogers (1943), whose infusion treatment of cholera requires no description. Enthusiasm in ' pushing ' Roger's line of treatment often resulted in the adverse manifestations of overdosage.

Between the two wars great advances in knowledge relating to water and salt balance, and the maintenance of body osmotic pressure, were made in England, America, France, Switzerland, and other countries. The fluid ' compartments ' of the body were demarcated; experimental studies of water and salt depletion were undertaken, and the vast importance of maintaining the normal osmotic relations of the body-fluids became apparent. The basic principles so realised were applied to the treatment of dehydrating diseases, and to the special problems of dehydration in infancy, in ship-wrecked sailors, in soldiers engaged in desert warfare, etc.

Gamble (1947) in America, was one of the pioneer investigators into the complexities of fluid balance. Kerpel-Fronius (quoted by Marriott, 1947) and McCance (1938) were the first to emphasise the separate effects of water and salt depletion. Pure water and pure salt depletion often occur, though mixed cases are usually encountered. In mixed cases it is important to determine whether water or salt depletion is the predominant dehydrating factor. These considerations are important, because although dehydration is the end result of both water and salt depletion, the mechanism whereby it is produced is totally different in each case. Further, if the wrong treatment is instituted; that is, if water is given to a case of salt depletion, or *vice versa*, the condition is made worse. The importance of a clear knowledge of the principles of water and salt therapy has been proven. Many deaths have resulted, and still result, from incorrect treatment.

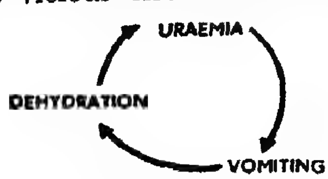
During the war years, Nadal, Pedersen and Maddock (1941), in America, successfully applied experimental principles to clinical requirements. Along with other tropical countries, India provided an admirable setting for proving the value of rational water and salt therapy. Marriott contributed in a very large measure to a greater understanding of this important subject. He has since published an excellent review of water and salt depletion (Marriott, 1947) which merits careful study. The state of knowledge at the end of the war is summarised below :—

PHYSIOLOGICAL PRINCIPLES

Water constitutes 70 per cent. of body-weight. A greater portion of this (50 per cent. of body-weight) is intracellular fluid, the rest being extracellular fluid. The extracellular fluids are made up of tissue fluid, which is the fluid of the tissues between the body cells; and the circulating fluids, the chief of which is plasma. The tissue fluid constitutes about 15 per cent. of body-weight, and plasma only about 5 per cent.

Body-water may be visualised as occurring in three separate compartments, viz., the intracellular compartment, the interstitial compartment and the vascular compartment. Under normal conditions the relative volumes of fluid in these compartments (about 3 litres in the vascular compartment, 11 litres in the interstitial compartment and 35 litres in the intracellular compartment) is kept constant by the osmotic pressure of plasma proteins and electrolytes. Nutritive substances are carried from the plasma to the cells by way of tissue fluid and the waste products of cellular metabolism are removed in the opposite direction. Fluid leaves the vascular compartment at the proximal end of capillary loops by passing through the capillary walls because the hydrostatic pressure is greater than the osmotic pressure exerted by the plasma proteins. At the distal end of the capillary loops, hydrostatic pressure falls below the osmotic pressure, and fluid returns to the capillaries by osmotic attraction. The plasma volume is thus kept constant.

Cell membranes are freely permeable to water, and the distribution of water in the 'compartments' depends on the relative osmotic pressures of the fluid in each compartment. The maintenance of isotonicity of the tissue fluid is of profound importance. Changes in tissue fluid tonicity will result in accumulation in or withdrawal of water from the cells. Water intake or loss first produces changes in the tonicity of the extracellular fluid. A state of osmotic normality is dependent upon normal water and salt balance, i.e., on a state in which the intake of water and of salt covers requirements. Any excessive intake of water is excreted. The daily output of water in an average adult in a temperate climate is about 2,600 c.c., which is made up of 1,500 c.c. of urine, and 1,000 c.c. lost by evaporation (sweat and expired air) and 100 c.c. in the faeces. Under tropical conditions, the total loss may increase threefold, relatively more being lost as sweat and relatively less as urine. If water intake is cut off, water loss continues, about 1,000 c.c. by evaporation, and, at least 500 c.c. as urine, daily. If the concentrating power of the kidneys is impaired, a greater amount of urine will be necessary to remove nitrogenous waste, and if a suitable amount of urine is not excreted, uraemia will develop more rapidly. Impaired renal concentrating power is frequently present in dehydration and patients may enter the vicious circle shown below :—



Salt intake, which is about 10 g. daily, usually exceeds requirements, and the surplus is excreted in the urine. If the intake is cut off, salt is conserved by the excretion of a smaller quantity, or none at all in the urine.

Dehydration may arise from pure water depletion, pure salt depletion, or from a combination of both.

Pure water depletion arises as a result of water and salt deprivation. Water loss continues, but salt is conserved. Pure salt depletion arises from salt and water loss, e.g., excessive sweating, severe diarrhoea, persistent vomiting, etc., with replacement of water only. Mixed depletions arise as a result of water and salt loss and inadequate water and salt replacement. This is very common in febrile states, and in any other condition in which a patient is too weak to drink enough.

The osmotic differences between pure water depletion and pure salt depletion are of great importance. In water depletion the extracellular fluid becomes hypertonic because water is lost without parallel salt loss. Water is, therefore, withdrawn from the cells and thus the volume of the extracellular fluid tends to remain constant. In water depletion, therefore, the dehydration is intracellular. In salt depletion the extracellular fluid becomes hypotonic because of loss of electrolytes. The kidneys endeavour to correct this by excreting water so that the extracellular fluid volume falls. The body cannot retain water in the absence of salt. Salt depletion dehydration is, therefore, an extracellular dehydration. Because of the osmotic action of the plasma proteins, this loss is greater in the interstitial compartment than in the vascular compartment. Nevertheless a fall in plasma volume results.

CLINICAL MANIFESTATIONS

Pure Water Depletion : Increasing thirst with a dry mouth and tongue occurs early. There is oliguria and progressive weakness, and the face becomes ashen grey. Temperamental characteristics may become exaggerated. Mental power may be affected, and there may be confusion and hallucinations. The sodium and chlorine content of the plasma rises, as also the blood urea. There is little change in plasma volume and hardly any haemo-concentration.

Salt Deficiency Dehydration : In this type of dehydration extreme lassitude and apathy may be present and may progress to stupor. (Mild lassitude and apathy are common features in the tropics). There may be muscular weakness. There may be a tendency to giddiness and fainting on assuming an upright position. A continuous mild headache is not uncommon. Urine volume is normal, or increased if the patient is ingesting sufficient water. After drinking a large amount of water, diuresis does not develop for several hours. This delayed diuresis is due to delayed absorption of ingested water. Chlorides are usually diminished and may be completely absent from the urine. A very important manifestation is the absence of thirst. There may be anorexia, nausea and vomiting. There is considerable loss of weight. Loss of subcutaneous fat and of tissue fluid results in the skin becoming dry and inelastic.

The eyeballs become sunken and the intra-ocular tension falls. The bones become prominent and in extreme cases the skin of the fingers may become wrinkled. Cramps, particularly in the muscles used in an individual's daily work are very common. Mental changes occur in some instances. There is a fall in the plasma sodium and chlorine and blood urea rises. There is a fall in plasma volume, and haemo-concentration may be marked. Blood-pressure may be below 90 mm. Hg. and the blood viscosity is increased. If the fall in plasma volume is profound the patient enters a state of peripheral circulatory failure identical with the shock syndrome.

In many conditions involving loss of electrolytes there may be changes in the body's acid-base equilibrium. The changes in acid-base balance are, however, secondary to disordered electrolyte balance and can usually be corrected by restoring the electrolyte balance, e.g., the acidosis of cholera can usually be corrected by restoring sodium-chloride balance.

ASSESSMENT OF THE AMOUNT OF WATER DEFICIT

Water Depletion : If there is thirst only there is an approximate deficit of $1\frac{1}{2}$ litres. If there is thirst with a dry mouth and tongue, oliguria and weakness, there is an approximate deficit of 4 litres. In very severe cases with considerable impairment of mental and physical capacity there may be a deficit of 5 to 10 litres.

Salt-depletion Dehydration : If there is lassitude, giddiness and fainting on standing, there is an approximate deficit equal to 4 litres of isotonic saline. If urinary chlorides are absent and if there is anorexia, nausea and vomiting with the systolic blood-pressure above 90 mm. of mercury, there is a deficit of about 5 litres. If the systolic blood-pressure is less than 90 mm., there is an approximate deficit of 8 litres. The above figures pertain to an average man weighing about 10 stones. The degree of water deficiency in salt depletion may also be determined by measuring the specific gravity of the blood, preferably by some rapid method, such as that of Phillips, Van Slyke, Dole, Emerson, Hamilton and Archibald (1943). If the specific gravity of blood rises to 1,063, it indicates a deficit of 3 pints (about $1\frac{1}{2}$ litres) ; if 1,064 it indicates a deficit of 4 pints (about 2 litres), and so on. It may be more useful to calculate the amount of plasma loss from the formula :—

$$\text{Plasma loss (in litres)} = 5 - \frac{(5 \times \text{Hb1})}{(\text{Hb2})}$$

where Hb1 = 100 per cent. and Hb2 is the haemoglobin percentage in the patient. The haemoglobin percentage can be rapidly calculated from the blood and plasma specific gravities from Phillips, Van Slyke and others' line chart. Marriott suggests that the plasma deficit multiplied six times gives the extracellular fluid deficit.

TREATMENT

Dehydration is a feature of many diseases in India such as dysentery, cholera and heat effects. It is present in most febrile states as the result of excessive fluid loss usually with inadequate fluid replacement. Far more fever cases die of dehydration than is realised. These deaths are due to lack of understanding of the pathological principles involved. The following outline of the incidence of one of the conditions mentioned above may serve to indicate the prevalence of dehydration. In 1942, an extremely hot year, there were many cases of heat exhaustion in the country. Of these cases, 1,405 cases occurred in British troops, with 27 deaths, and 255 cases in Indian troops, with 13 deaths. There were many more Indian troops in the area, so the incidence among British troops was much greater, though the mortality rate was higher among Indian troops. In the same year troops in Persia and Iraq Force were subjected to extreme heat, the hospital admission rate for heat effects being 17·5 per 1,000 (British 88·7 and Indian 3·27). Mortality per 100 cases among British and Indian troops was 1·35 and 8·87, respectively.[1]

Another important practical aspect of dehydration in hospital patients in the tropics is the maintenance of adequate hydration in patients on sulphonamides. An inadequate output of urine in such cases may result in renal failure. Marriott (1947) introduced a useful device to prevent such occurrences. He provided soldiers undergoing sulphonamide therapy in hospitals in India and Burma with old glass rum jars with a red ring painted around them to indicate the 2 litre level. Each patient was told that he must pass urine up to that mark every day or he would die. In Marriott's own words " this clear demonstration of the purpose before him plus its automatic action as a reminder achieved what exhortation failed to do ". The principles of treatment of this important condition which were adopted in India can now be outlined.

Dehydration is treated by the intelligent administration of fluids and electrolytes. If salted fluids are administered to a case of water depletion, the already existing extracellular hypertonicity will be aggravated and the cellular desiccation increased. If water is given to a case of salt-deficiency dehydration, the hypotonicity of the extracellular fluid will increase and this is corrected by increased excretion of fluid via the kidney. Pure water loss should, therefore, be compensated for by administration of water, water and sodium chloride loss by water and sodium chloride therapy till a state of adequate hydration is produced. When a state of adequate hydration is produced, the manifestations of dehydration disappear. One of the most important criteria of adequate hydration in water depletion is the passage of at least a pint of urine every 8 hours. This enables the body to perform the essential functions of excreting 35 g. of nitrogenous waste products a day, and so offsets the ill-effects of their retention.

[1] See also page 165.

It is essential to make a preliminary assessment of the fluid deficit based on the clinical data suggested above, so that the amount infused should roughly equal the amount lost.

It will be appreciated that properly compiled fluid chart showing output and intake should be conscientiously maintained. It should be borne in mind, however, that in salt-depletion dehydration, the urinary output may be normal or raised and that gross dehydration may exist in the presence of a balanced fluid chart. The easiest and best route of administration is the oral route because this is the natural route. The fluids of choice for administration by mouth are either water or salted water depending on the type of dehydration (half a teaspoonful of salt to one pint of water) and hot sweet tea. In 1943, Ransome, Gupta and Paterson (1944) at No. 52 IGH, Gauhati (Assam), showed that in cases in which the patient cannot drink, because of unconsciousness or for any other reason, fluids can still be introduced into the alimentary canal by means of a transnasal intragastric Ryle's tube. By this means hydration can be continued during sleep and fluid intake can be easily measured. Food and drugs may be administered by the same route. There is no risk of pulmonary oedema. Further, pyrogen free fluids are not necessary for introduction into the alimentary tract. No injury to the nasopharynx, oesophagus or stomach has been reported.

Unconscious cases which may require hydration by means of a Ryle's tube are divided into three groups:

Group I : Those in whom a swallowing reflex is present.
Group II : Those in whom the swallowing reflex is absent.
Group III : Maniacal and cerebral irritation cases.

Group I: The patient is made to sit up and a well lubricated tube is passed through the nostril along the nasopharynx. The patient will start to cough and retch and one should wait until he swallows. As he swallows the tube should be pushed on.

Group II: The patient is propped up. Using a mouth gag two fingers are passed into the mouth to guide the tube (which is passed through the nostril) into the oesophagus.

Group III: These patients are best given a small dose of intravenous pentothal sodium sufficient to quieten them without abolishing the swallowing reflex. If the swallowing reflex has been lost, one should wait until it returns. When the tube has been passed, paraldehyde in adequate dosage should be given through the tube to keep the patient quiet.

It is important to make sure that the tube is actually inside the stomach by aspirating a little of the gastric contents.

A useful adjunct to the oral or gastric route is the rectal route. Certain precautions should be taken concerning rectal administration of fluids. The lower bowel should not contain any faecal matter because this will prevent absorption, and so rectal administration should be preceded by a thorough colonic lavage. The ideal fluids for rectal administration are tap water or half isotonic saline. Glucose should

not be used because it is an irritant, and furthermore it is hardly absorbed. The reservoir should not be more than one foot above the rectum. Wide bore tubing should be used. The success of rectal administration is dependent on the tight grip of the anal sphincter on the nozzle or tube. If the intrarectal tension is increased by using a high reservoir the sphincter tends to open. Wide bore tubing facilitates the passage of flatus and so prevents distension of the rectum by this means. The lower bowel can absorb up to 2½ litres daily.

The subcutaneous, submammary and intramuscular routes are hardly used because absorption is slow. There is often pain, and septic complications are prone to result. The intraperitoneal route has been used with advantage particularly in the treatment of dehydrated babies. Absorption is rapid, but there is always danger of peritonitis. Saline infusion into the bone-marrow of the sternum or tibia has been recommended but would hardly appear necessary except in rare instances.

The intravenous route is used only in cases of emergency, and when the alimentary route cannot be used. The fluids of choice for use by this route are :—

Isotonic saline (0·85 per cent. sodium chloride).
Isotonic glucose (5 per cent.).
Isotonic glucose saline (0·425 per cent. sodium chloride and 2·5 per cent. glucose).

In pure water deficiency isotonic glucose is the fluid of choice. The first two or three pints may be given in 15 minutes each, but the remaining fluid should be given at one pint in 4 hours till a state of adequate hydration is achieved. In 'pure' salt depletion isotonic sodium chloride should be administered at the above rate and in mixed cases isotonic glucose and isotonic saline in varying proportions depending on whether the predominant deficiency is of water or salt, respectively. Saline overdosage is prone to result in pulmonary oedema, particularly when the osmotic-pressure of the blood is lowered as a result of depletion of plasma proteins through haemorrhage or plasma loss. In such cases a suitable quantity of plasma should be infused before the saline. Severe pulmonary oedema also results readily in conditions in which a milder form is pre-existent, e.g., heat hyperpyrexia. In India, Ransome Gupta and Paterson (1944) demonstrated that if infusions are given with the patient in Fowler's position the tendency to pulmonary oedema is lessened. A fatal issue has very often been provoked in cases of heat effects by over-zealous intravenous saline administration, especially in cases of sudden onset, due to failure of temperature control, in which very little salt and water depletion existed. As intravenous salinisation is not to be undertaken lightly because of the tendency of overdosage to produce pulmonary oedema, a careful lookout for danger signs should be maintained and a check should also be kept on the progress of the therapy. Repeated examinations of blood-pressure should be undertaken, and the pressure should not be permitted to rise above 110 mm. of mercury. The bases of the lungs should be repeatedly examined, because the appearance of basal rales is an early sign of pulmonary

oedema. The urinary output should be measured eight-hourly. An estimation of urinary chlorides can give a useful indication of the chloride content of the body. The amount of chloride in the urine may be rapidly and simply determined by means of the following test (Fantus, 1936).

Ten drops of urine are taken in a test-tube. To this, one drop of 20 per cent. potassium chromate (not bichromate) is added. Then 2·9 per cent silver nitrate is added, drop by drop, and the mixture well shaken after each drop, till a permanent change of colour from canary to brown takes place. The number of drops of silver nitrate required gives the number of grammes of sodium chloride contained in one litre of the urine. The same pipette washed thoroughly with distilled water each time should be used throughout (as potassium chromate often contains sodium chloride as an impurity a control should be done using distilled water instead of urine, and a correction made to the test result if necessary).

To prevent dehydration in the tropics adequate water and salt intake is essential. Fifteen pints of water and 3/4 oz. of salt may be required each day under very hot conditions.

It is now appreciated that the treatment of water and salt depletion is not a simple matter ; it is a task for the expert and should not be delegated to inexperienced medical officers and nurses.

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CHAPTER VIII

Dermatology

(i) ADMINISTRATION AND ORGANISATION—DERMATOLOGY SERVICE

ADMINISTRATIVE DIFFICULTIES

It is no exaggeration to say that before the war dermatology in the literal sense of the word was neglected by the army. The designation 'dermatologist' was a term that concealed the activities of the venereologist. When the great loss of manpower from dermatological affections during World War I is considered, the subsequent disregard of the subject both by the Indian and the British armies is amazing. In India there was a peace time establishment of 7 dermatologists before the war, and the establishment was not altered until the war was half over. An adviser in dermatology at the GHQ India was appointed in February 1943, to supervise both venereology and dermatology. He obtained sanction for the number of specialists to be increased first to 18 and then to 64. Specialists to fill these vacancies were not available, nor could the full complement be drawn from sources outside India. The problem of the prevention and treatment of venereal diseases in the troops in India was urgent and took most of the adviser's time and attention, although the problem of dermatology was nearly as pressing. Those venereologists who had some knowledge of dermatology also undertook the treatment of skin cases which began to be collected in the hospitals near or at venereal diseases centres. A trained dermatologist arrived and after discussing the situation with the consultant physician Eastern Army, in addition to routine duties, began to hold courses in dermatology for medical officers. Arrangements were also made for them to attend the dermatological out-patient department at the School of Tropical Medicine, Calcutta. Lack of accommodation both in the military hospitals and in the School of Tropical Medicine restricted the numbers to four a month: this number was, increased to eight by the end of 1943.

In 1942, admission to hospitals for skin diseases, including scabies and minor septic conditions averaged 76·7 per 1,000 for Indian troops and 93·2 per 1,000 for British troops. In 1943, the ratios had risen to 97·6 per 1,000 for Indian troops and 96·6 per 1,000 for British troops. Scabies was not officially classified as a disease of the skin needing the attention of a trained dermatologist but came under the province of hygiene. Admission to hospitals in 1942, for scabies and its complications was 19·1 per 1,000 for Indian troops and 9·5 per 1,000 for British troops. In 1943, the ratios had risen to 27·2 per 1,000 for Indian troops and 13·6 per 1,000 for British troops. The problem of dermatology had

become more urgent, and on 21 July 1943, the adviser in dermatology became what he was in fact, the adviser in venereology, relinquishing the supervision of skin diseases to a new adviser in dermatology. A separate dermatological service had to be built up and also required an establishment. This task included the finding or training of specialists, the search for nursing sisters with a liking for dermatology to take charge of the skin wards, the training of nursing orderlies and sepoys, the acquisition of the simplest instruments, the quest for drugs commonly used by dermatologists, and the formation of dermatological centres in which the special service could be used to the best advantage. Although the two subjects had been separated at GHQ, the treatment of skin diseases was still mainly in the hands of the venereologists, still called dermatologists, because there were not enough medical officers with any dermatological training to take over. The confusion arising from the classification of the two specialities and their specialists under one official designation and an inability to get equipment suitable for the dermatologists until a definite scale had been established made it desirable to separate the two completely as early as was practicable. Accordingly the combined pool of specialists for dermatology and venereology was divided in January 1944, an establishment of 24 specialists being allocated to the pool of dermatologists. As a result of this division two IAMC and five RAMC specialists of the combined pool came into the dermatological section. The serious shortage of personnel for the pool was lessened at the beginning of 1944 by the arrival of one recognised and three graded specialists from the United Kingdom and one IAMC graded specialist from the Persia and Iraq Force. One RAMC graded specialist from Middle East Force joined the pool in April 1944.

Courses in dermatology for possible specialists were given by Major A. Bigham, RAMC at the CMH, Barrackpore, and of those who attended the courses, 13 were selected and became graded specialists in the first half of 1944. Unfortunately five officers had to leave the pool, chiefly through illness, so the pool was still below strength. Courses had to be transferred from Barrackpore to Poona owing to the preoccupation of Major Bigham with duties as adviser to the deputy directors of medical services, (DDsMS) Eastern Command and the Fourteenth Army.

An increase to 39 in the establishment for the pool of specialists was requested and was sanctioned in July 1944. Towards the end of the year a further increase was sought for the following reasons:

(i) Owing to the wide dispersal of forces in Allied Land Forces South East Asia (ALFSEA) the medical services needed more dermatologists both in hospitals and in forward areas to prevent the early cases from being sent back for treatment.

(ii) For some centres in India no specialist was available and other centres were understaffed, because the allocation to separate hospitals of patients from ALFSEA and patients from garrison troops, sometimes several miles apart, made it impossible for one man with untrained staff to exercise adequate supervision over two or more hospitals.

(iii) Specialists from the United Kingdom were expected and on arrival had to be accommodated within the establishment.

(iv) There were already trainees in India who would shortly be suitable for grading.

An increase from 39 to 60 in the establishment of specialists was, therefore, authorised in May 1945.

During 1944, three RAMC officers became recognised specialists in dermatology, and the following numbers were graded : 12 IAMC, 15 RAMC and one civil medical practitioner. The appointment of adviser in dermatology at GHQ was upgraded to that of consultant on 31 October 1944.

Although dermatology in ALFSEA was no longer part of the province of the consultant at GHQ, the dermatologists in that force still remained part of the pool, on which increasing demands were made by ALFSEA.

The courses for the training of specialists were transferred from Poona to Barrackpore by the middle of 1945. Poona was a less suitable place for training, because the type of cases that occurred most frequently in the field were less often seen there on account of its distance from the seat of operations, and its better climatic conditions reduced the incidence of such affections in the local troops. Also, the dermatological patients in Poona had never been located in less than five hospitals scattered over the district, and shortage of transport made it difficult for the specialist and the trainees to get around. The specialist had, in addition, to give lectures and demonstrations regularly to the medical officers passing out of the Army Medical Training Centre, Ganeshkind.

The provision of appointments of advisers in dermatology at the headquarters of armies and commands was sanctioned on 4 April 1945. Until that time the senior specialist in the Eastern Command and in the Southern Army had acted as un-official adviser to the DDMS, whenever required and also made local tours.

When the consultant in dermatology left India in October 1945, 46 officers had been trained and graded, but the pool had never reached its full complement owing to the losses from evacuation of the specialists through illness. The shortage of recognised specialists was so severe that none was available for the Central Command until September 1944, and for the North-Western Army until 1945.

Despite the inadequacy of numbers the beneficial effects of the exertions of the dermatologists outside the hospitals to which they were attached began to be reflected in the hospital returns. In 1944, the ratio for admission to the hospitals had fallen to 64·8 per 1,000 for IORs and 62 per 1,000 for BORs.

The training of dermatologists in adequate numbers in a short time was hampered by the restrictions placed on the training of young officers (below 37 years) as specialists in order to save young category 'A'

officers needed for forward units.[1] This debarred younger officers with some experience of dermatology from receiving specialist training. The policy of trying to train older men intensively proved to be unsatisfactory ; in older officers the proportion of failures to pass the required standard after a course was much higher. In the rapid training of a specialist some previous experience of the subject is much more helpful than his attaining the age of thirty-seven years. Fortunately the restrictive policy was abandoned, and by the time the war had reached its final phase, some young men had been trained to work and were working in the forward areas.

The variety of skin disorders that prevail in the army is much less than in civil practice, and had the elementary principles of diagnosis and treatment been thoroughly understood by all medical officers, the number of patients needing admission to hospital would probably have been halved and the time spent in the hospital by the remainder in many instances effectively curtailed. Unfortunately this knowledge was not possessed by many medical officers.

No establishment of beds to accommodate skin diseases was sought. When a dermatologist was posted by the consultant to a hospital he became the nucleus around which a centre grew, and he was allotted beds in one or more wards. Owing to the persistent shortage of specialists, attempts were made to keep the number of centres at a minimum, but this did not fit in with the plans of medical organisation. The prospect of having large numbers of dermatological and (or) venereal diseases patients in a hospital, was unpopular with some commanding officers and higher administrative ranks. In early tours particularly, an impression was given that any building would suffice to house skin patients. The wards were usually buildings that were badly sited and otherwise unsuitable ; in fact, accommodation that had been rejected as quite unfit for medical or surgical cases. Until the separation of dermatology and venereology, both types of patients not infrequently shared the same wards and small overcrowded dining halls. Inevitably all incurred the same stigma, and so dermatological cases were denied privileges given to the ordinary patients. A standard schedule of accommodation and line drawings when issued in 1944, did not include any plans for dermatological wards, special treatment rooms and bathing facilities. Adequate provision for these cases was not authorised until January 1945, after which standard plans were made and issued. Treatment rooms with baths, sinks and an adequate supply of running water were needed to carry out work rapidly and efficiently. With a poor water supply and makeshift facilities the incidence of cross-infection in the wards, a matter as important to the dermatologist as it is to the surgeon, was always high. It was impossible to get any wards fly-proofed. No air-conditioned wards were available. They were necessary during the summer for the rapid healing of certain types of skin cases, and in the absence of such wards many men who did not need the other advantages of a hill station had to be sent there. The

[1] A/2/57/H (M).

adviser in dermatology Eastern Command, stated that "If we are unable to clear a soldier by skilled treatment in the plains, then that soldier is of no use for the type of country the Fourteenth Army has to fight in". The consultant in dermatology agreed with this view. Where really adequate facilities were available, as at Barrackpore, the DDMS, Eastern Command, said of them "They prove the case that trained officers with trained orderlies, together with certain necessary facilities, can achieve results in Bengal far beyond the powers of untrained officers and men in the best hill stations". Dermatological wards were established at Lebong and Shillong mainly for the British troops.

The Chief Principal Matron approved the suggestion of the consultant that the nursing of dermatological patients should be supervised by nursing sisters. The shortage of nursing sisters did not allow these wishes to be fulfilled in many British hospitals. Indian hospitals, though with a greater number of beds per nurse, seldom had a full complement of nurses, and in these hospitals the need for supervision of the nursing sepoy, often with a low standard of training, was greater still.

The problem of obtaining capable nursing orderlies and nursing sergeants adequately trained for duty in dermatological wards generally remained unsolved. The least efficient men were usually allocated to these wards, and changes in personnel were frequent; consequently adequate training in the dressing of skin lesions was seldom acquired by those who passed through these wards. The War Office refused to make a dermatological orderly's work a separate trade, so the dermatological orderly then had no special status. Special orderlies were very necessary in Indian hospitals, because in a busy ward it was almost impossible for the nursing sister to exercise adequate supervision over unskilled nursing orderlies and sergeants. At the CMH, Barrackpore, a number of them were adequately trained over periods of three months, and the Eastern Command ensured that those who were transferred elsewhere in the command continued to work in dermatological wards. A short paper was written for the IAMC preliminary training school and a syllabus for twelve lectures to be given to medical officers and nursing sergeants was drawn up.

In most theatres of war it was found necessary to allocate 10 per cent. of the beds for the sick (not wounded) for the treatment of skin diseases, including scabies. Most cases of inflammation of areolar tissues admitted to surgical wards began as some lesions of the skin which did not receive skilled treatment in the early stage.

EQUIPMENT

Indian Army Form (IAF.Medl. 29/81A) containing the medical mobilisation equipment (MME) scale for the dermatological centre was published on 11 February 1944. It was based on the Amendment 25 to Appendix 31 of the *Regulations for the Medical Services of the Army* 1938. Although the equipment listed in it was the minimum, hardly

any of the items was available at the time. However, most of the items had come from the United Kingdom by the time hostilities had ceased.

A certain amount of superficial X-ray therapy had been given at several civil hospitals in India from the early days of the war, but this arrangement was not entirely satisfactory from several aspects. At the end of 1944, four superficial X-ray therapy sets arrived from the United States of America (USA) and were installed in co-operation with the consultant in radiology. The first set was working by the spring of 1945. Two additional sets were ordered but did not reach India before the end of the hostilities.

DRUGS

Some drugs required for dermatological use were not readily available. The most serious shortage was of those used for treating scabies. Very small quantities of benzyl benzoate and Lanette Wax S.X. were available until the early part of 1945. At one period the supply of sulphur ointment was so short that an old stock of Danish ointment had to be used for the treatment of scabies in the Southern Army. Penicillin was available in quantity early in 1945 and greatly shortened the time taken to clear certain pyogenic infections of the skin.

(ii) HYGIENE OF THE SKIN IN THE EASTERN THEATRE OF WAR

The incidence and duration of the skin diseases was certainly much higher than the official figures state, because many minor conditions and the lesser degrees of the major ones were not reported or detected, and if seen were not recorded. Nevertheless, all caused some disability and loss of efficiency in the troops, and in many instances the origin was a defective hygiene of the skin.

The essentials of dermatological hygiene are to keep the skin clean and to allow it to carry out its great function of keeping the body temperature normal. Neglect of the former predisposes to pyogenic infection and of the latter to serious disturbances of the general health. Next in importance is to keep the skin free from parasitic infection. Troops in the eastern theatres of war were drawn from many races. Their standards of personal cleanliness and methods of cleaning the skin varied widely. Some were accustomed to thorough washing with soap, others were not. There was unfortunately no free issue of soap to develop the habit of cleansing the skin and their clothing. Not only should soap be issued to the troops, but the possibility of issuing a medicated soap should also be investigated. Some soap impregnated with 'tetmosal' for the prevention and cure of scabies came from the United Kingdom but not in sufficient quantity for a large scale field trial on labour companies, the most heavily infected units. Primitive methods of washing are not capable of destroying all the organisms in pus that has dried on clothing, and mobile laundries were few and widely scattered. The greatest incidence of skin sepsis was on the legs. In

some camps, depots and even hospitals the water supply was grossly inadequate for the demand, e.g., the camps at Deolali and No. 62 IGH at Dacca. In winter no fuel was available for heating washing-water in most of the stations in the North-Western Army.

The problem of assisting and not hampering the skin in its task of regulating the body temperature varies with the humidity of the climate. In the hot dry season sweat evaporates readily, and the skin should be covered by clothing sufficiently thick to arrest excessive radiation of heat from the sun and the ground. The air temperature in the monsoon is low and the rate of sweat secretion is also low, but in the highly humid air a much smaller amount of sweat evaporates, so the skin becomes sodden with moisture and loses some of its self-protective powers. The areas most affected are the perineum, genitocrural region, axillae and also other areas where the clothes were pressed tightly to the skin by belts and equipment. When the surrounding air is nearly saturated with moisture, convection is minimal and there is little air movement over the skin. This circulation of air was further impeded by wearing trousers instead of shorts on the eastern front, because the former protected the legs better against insect bites and other mild forms of trauma. Consequently, though cuts and scratches turned septic less frequently, the incidence of prickly heat and fungus infections of the body increased. Prickly heat affected British troops more, but both Indian and British troops suffered from intertrigo and fungus diseases.

In hygiene of the feet, higher standards could have been achieved. Many Indian troops wore boots that were too large and ill-fitting, and a number of recruits who had been accustomed to going barefoot in civil life developed crippling callosities. The supply of foot powder was inadequate until the last phase of the war. In jungle warfare boots often became waterlogged and the skin of the feet sodden. The need for some form of grease to waterproof the skin was not always realised.

The most serious lapse in hygiene was the lack of regular 'free from infection' inspections. Many recruits had obviously never had their skin examined at the first medical examination as witnessed by the number boarded out of the army for chronic skin diseases and even leprosy.[2] The presence of scabies as the underlying cause of many men presenting themselves with pyogenic infections of the skin was seldom considered by the regimental medical officer, some of them were incapable of recognising obvious signs of scabies. Even when the diagnosis was made, it was uncommon for the unit to be examined for other possible cases. The treatment of this infection and its complications was the dermatologist's heaviest task, yet scabies was not classified officially with diseases of the skin.

(iii) PRINCIPAL SKIN DISEASES IN THE EASTERN THEATRE OF WAR

The five main skin diseases in the forward areas, prickly heat, impetigo, mycotic infections, scabies and jungle sores, were all affected

[2] See page 227.

greatly by the excessive humidity of Bengal, Assam and the Arakan areas. Prickly heat became septic in a very short time unless adequate washing facilities, for clothes and bodies, were available. The fungus diseases, particularly tinea pedis and scabies, were also complicated in the early stages by sepsis. The excessive humidity together with heat proved the greatest obstacle to effective treatment throughout the whole of the forward areas.

SCABIES

Scabies was the most misdiagnosed skin disease. To the untrained eye there may have been some measure of excuse for missing the diagnosis, for in most cases in the forward areas the condition developed into a pyoderma in a very short time. The pyoderma was treated as a rule, but the underlying scabies, undetected, caused frequent relapse and prolonged hospitalisation. In fact these cases were found to have been in hospital for several months. It was noted that Indian troops frequently showed no lesions on the hands, possibly due to their clean habits following defaecation. It became the rule to treat with anti-scabietic measures all cases of itching at night associated with pustular lesions on the buttocks and genitals. This proved to be a sound rule. Sulphur ointment therapy was used in the first instance. This is quite effective if the technique is carried out scrupulously by trained orderlies. Too often it was found that the patient was given a pot of ointment and told to rub it in himself. Eventually benzyl benzoate emulsion became available, and this was much easier to handle. The main point to remember in benzyl benzoate therapy was that the washing of the patient should be carried out only ' before ' and ' after ' the two-day treatment with the emulsion. Scrupulous treatment by nursing orderlies was still necessary—painting from neck to toes, missing no part of the body (not just painting where visible lesions were situated).

SEPSIS

When sepsis was superimposed on prickly heat, the condition of tropical impetigo arose. This appeared as bullae of various sizes, particularly on the trunk and covered parts. The bullae were flaccid and showed a content of serum with a lower opaque layer of leucocytes, and by the uninitiated, a diagnosis of pemphigus was often made. When sepsis accompanied the mycotic infections, particularly of the feet, lymphangitis and adenitis were frequent complications. Scabies as mentioned above was nearly always septic scabies. The origin of the jungle sore was said to be a small abrasion which escaped notice and which became infected, resulting later in the fully established jungle sore. Considerable disability resulted from boils, carbuncles and axillae adenitis. Acne of the back became a considerable affliction when secondary infection set in and the soldier was unable to carry his pack.

In treating sepsis it was found wiser to restrict the use of the sulphonamides to internal use, owing to the risk of local reaction. Local measures—potassium permanganate baths and the dyes, e.g., gentian

violet and brilliant green were effective though later the use of penicillin, in spray form locally, and by injection, was invaluable.

IMPETIGO

Impetigo was widespread in incidence. It occurred both in its usual superficial form, and in the deep or dermic variety known as ecthyma. When a soldier with an underlying seborrhoeic diathesis became impetiginised, he at once constituted a major problem; indeed large numbers of these men (British troops) had to be invalided to the United Kingdom. Impetigo affecting the beard areas frequently developed into sycosis barbae, which again formed a major problem, and many of these patients had to be invalided from tropical service. It was obvious that seborrhoeic soldiers reacted unfavourably in tropical climate.

In regard to the treatment of impetigo, the use of sulphonamides, locally, was restricted to five days to avoid sensitisations. The older methods such as soaking in boric lotion, Alibour's lotion, gentian violet, Ung. quinolor, all produced good results if used intelligently. Later, penicillin spray (500 units per c.c.) was used with good effect—the spray was used every four hours.

SENSITIVITY TO DRUGS

A number of drugs in common use produced a dermatitis. The sulphonamides in particular were responsible for much prolonged hospitalisation. It was found that some septic skin lesions had been treated vigorously with a sulphonamide application, a dermatitis had been produced, and as it was thought that this was merely an increase in the infective process, more sulphonamide was applied. A generalised sensitivity then developed, often with toxic effects, oedema of the tissue, adenitis and a high temperature. Some attempts were made to desensitise these patients by giving very small doses of sulphonamide by mouth, but the risk in such a climate was deemed too great, for the initial period of toxicity was increased for a time before desensitisation could be achieved.

Another actinic sensitiser, acriflavine, was in common use. Many cases were seen in which a combination of sulphonamide and acriflavine had been used. In the brilliant sunlight of the Far East, many severe reactions took place. The remote effects of these drugs should be borne in mind—there may be a local reaction at the site of application, followed by an erruption of the exposed areas, and then the whole integument may become involved. Reactions to sulphur ointment and benzyl benzoate were found to differ in no great respect in India from other parts of the world.

A very interesting dermatosis resulted from the ingestion of mepacrine. In 1944, the Fourteenth Army was put on suppressive mepacrine therapy. Eventually a puzzling dermatosis arose in some of these troops. It often appeared as a scaling of the scalp and large

areas of the body, rather like a generalised seborrhoeic dermatitis. The true seborrhoeic areas, however, were not necessarily involved. Gradually large lichen planus like lesions appeared. They differed from lichen planus in having a deep purple areola, and the lesions were more pronouncedly warty. These cases (still on suppressive mepacrine in hospital) were all labelled ' resistant seborrhoeic dermatitis ' or ' chronic exfoliative dermatitis ' until the correct diagnosis became known. In some of these cases the lichen planus lesions formed the main feature. White plaques were seen on the mucous membranes of the mouth, and when they accompanied similar lesions on the prepuce had to be differentiated from secondary syphilide.

The treatment of all drug erruptions was to withdraw the causative factor. Affected personnel were withdrawn from the suppressive mepacrine areas. The mepacrine reaction was kept a close secret, for a great deal of unrest might have arisen had it become generally known that the daily mepacrine pill was the cause of this dermatosis, which, after all, only affected a very small proportion of individuals, whereas up to the introduction of mepacrine, malaria was decimating the Fourteenth Army.

MYCOTIC INFECTIONS OF THE SKIN

Fungi prefer to grow on those areas that are more moist and less acid than normal skin. The commonest situation in which they were found were, therefore, the groins, the area in and around the perineum, and the inter-spaces between the toes, particularly the fourth inter-space. These are areas subject to intertrigo. When the skin in the monsoon season was bathed in sweat, ringworm often spread rapidly and extensively over a greater part of the body and was particularly evident round the waist where the belt pressed. Infections between the toes were commoner in British than in Indian troops, because the latter, often accustomed to walk with bare feet, had toes more widely spaced and the skin of the feet was tougher and less often sweat sodden.

Adjacent moist areas of the skin that are in constant apposition and rub against each other develop intertrigo, a congestive erythema, in which some of the horny layer is lost and the surface is moistened with a thin fluid exudate. This reaction of the skin is not primarily eczematous but readily becomes so if treated injudiciously. The moist intertriginous surface favours the proliferation of bacteria and fungi which sometimes provoke an eczematous reaction. Intertrigo seems to have been a disorder unknown to most medical officers who, when confronted with the condition, made a diagnosis of tinea cruris or pedis and promptly applied fungicides. To this insult the skin usually reacted eczematously, and this was not infrequently regarded as an exuberant gesture on the part of the supposed fungus to be countered with stronger fungicides. Thus was initiated an obstinate chemical dermatitis necessitating admission to hospital often for long periods and made a number of British patients permanently unfit for service in the tropics. The mistake of diagnosing and treating intertrigo as a primary fungus infection was responsible for the loss of many man-hours and much invaliding.

The hair of Indian troops are practically immune from ringworm infection, but a serious epidemic of ringworm of the scalp was discovered in Gurkhas in September 1944. All Gurkha depots and training battalions were affected, because its existence, though present for months had not been reported. In some units at least 10 per cent. of the strength was infected. In many instances the reaction to infection was inflammatory, producing large kerions. Infected hairs were sent to the Tropical School of Medicine, Calcutta, for identification of the causal fungus. The specimen of hair were found to be infected with *Trichophyton gypseum*.[3] Precautionary measures were at once instituted, and all movements from these units were stopped. The epidemic was got under control at a cost of stopping all reinforcements to the Gurkha battalions. Wood's diagnostic glass was ordered from the United Kingdom and arrangements were made to install diagnostic lamps in all depots and adjacent hospitals. A superficial X-ray therapy machine was transferred from Ranchi to Roorkee for the epilation of infected scalps.

DERMAL LEISHMANIASIS[4]

The incidence of this condition was not high, because most of the troops were not stationed in the zone where this condition is endemic. Lesions were mostly of the dry type which ulcerated at a comparatively late stage. Secondary diphtheritic infection was an occasional complication in the ulcerated stage. From the military aspect the most satisfactory treatment was excision or curettage, because the lesion was soon healed and the patient was fit for duty in less than one month. All forms of injection therapy took longer and were less satisfactory.

JUNGLE SORES

This comprehensive term was given to the true tropical ulcer, to shallower ulcers of a similar type, and to certain other ecthymatous lesions, the outstanding feature of all being chronicity and slow response to treatment. These sores kept the hospital beds occupied for long periods and caused a serious wastage of manpower. They developed not only in conditions of active warfare but were common also, during the monsoon, in recruits training in certain peace time stations in India.

Histological sections of ulcers made in the Southern Army showed an abundant presence of a fusi-form bacillus deep in the floor of the ulcers. At times diphtheroid organisms recovered from smears were mistaken for diphtheria bacilli and the cases were wrongly regarded as diphtheritic ulcers. At one period a true secondary diphtheritic infection of jungle sore was found in casualties returning from Burma. This complication always arouses a great deal of medical interest, but from the military aspect the effect on manpower has always been small.

[3] See also Ghosh L. M., Dey N. C. and Panja, D. (1947). *Indian med. Gaz.* **82**, 73.

[4] See also page 205.

Some dietetic deficiency was supposed in many instances, but ulcers were common in the fit and perfectly healthy. The predisposing cause in practically all cases was some trauma, often trivial, which did not or could not be given early prophylactic treatment.

Symptoms: Somewhere below the level of the knee was by far the most common site for jungle sores. The early stage was often a painful superficial blister containing purulent fluid with hardly any inflammatory reaction around. Such a lesion could develop in a few days into a fulminating necrotic ulcer several inches across and penetrate to the muscles and tendons. The base of the ulcer was more or less filled with greyish black necrotic tissue resembling necrotic gangrene and had a foul smell. The borders became undermined and fringed with necrosing skin. This stage of the invasion was very painful and there were no signs of reactive inflammation. Then signs of inflammatory reaction appeared and the ulcer settled down to a chronic stage. The borders became indurated, and most of the necrotic material was cast off leaving a base covered with irregular, granulation tissue from which pus discharged freely.

Treatment: All cuts, scratches and other minor injuries should be treated as early as possible. The area should be cleaned with soap and water followed by an application of antiseptic lotion such as liquor iodi mitis or tincture benzoine co. The coagulation of fibrin on the surface of the wound will itself often form an adequate dressing. Ointments should not be applied, and covering with strapping is inadvisable.

When a case presents itself for treatment at the stage of a purulent blister, this should be cut away, the contents mopped up and wet dressings of hypertonic sodium or magnesium sulphate applied until the base is covered with clean firm dry granulation tissue. If left undisturbed at this stage under a sterile dressing, the ulcer heals fairly quickly. The course will be shortened if the patient is not allowed to be up and about. In the ulcer stage the patient must be strictly confined to bed in the hospital, and treatment is first directed at the removal of dead tissue and exposure of the underlying active infection. There are various methods of removing debris : it can be done with caustics, e.g., covering with powdered potassium permanganate crystals, painting with a solution of copper sulphate drachm two, phenol drachm one, glycerine drachm one night and morning, or by using a solvent such as a saturated solution of urea. Sometimes it is better to curette the dead tissue and trim the debilitated skin margin with scissors before applying hypertonic wet dressings. Some prefer to fill the ulcer with a powder of equal parts boric acid, iodoform and a sulphonamide until the stage of clean dry granulations is reached. As tropical ulcers sometimes take months to heal and may leave a large scar in some pressure areas which may necessitate lowering the ultimate medical category, the possibility of shortening the stay in the hospital by surgical intervention should be considered at the different stages, e.g., total excision where feasible, curettage and skin grafting.

Diphtheric infection was at times a complication of jungle sores. The treatment for this was general and not local beginning with at least

40,000 units of diphtheria antitoxin intramuscularly. An unusual complication was a non-suppurative osteoperiostitis in bones distant from the ulcer.

PRICKLY HEAT

This was responsible for much inefficiency, not only because of the great liability to pyogenic complications or the sequelae of tropical anhidrosis and asthenia but also on account of the irritation causing serious loss of sleep. Peace time conditions with troops quartered in shady barracks gave no idea of its incidence and severity in the field, particularly in Eastern India and in Burma. Not only British but also Indian troops and some African troops were seriously affected. An inquiry into the aetiology, prevention and treatment of prickly heat was requested by the Director General, Army Medical Service in the United Kingdom in December 1943. Accordingly preparations were made for clinical and experimental investigation, but shortage of staff and equipment greatly hindered the progress of the enquiry. The histological part was completed and the findings of Dr. O. Gans of Bombay, who undertook that part of the work, were similar to those of an investigation carried out for the Australian Army Medical Corps.[5] Histological changes found by Dr. Gans in section from biopsies in early cases were as follows :

" In the beginning the stratum corneum round the mouth of the sweat-duct and the most superficial cells in the entrance of the latter appear swollen as by imbibition. At a later stage the swelling is definitely oedematous. Primarily intracellular, it presses the wall of the porus together and finally this is blocked. An intracellular oedema appears about the same time in the epidermal part of the sweat-duct cells. Up to now there is no change in the pars papillaris cutis surrounding the sweat-ducts.

In a more advanced stage the cells pressed together at the mouth of the duct are pushed upwards, it appears by the sweat coming up from the gland. This is when clinically the skin looks a little like goose-skin. The accumulation of sweat in the porus increases and the latter develops into a dilated cyst-like structure. Small vesicle-like cysts may appear in the surrounding epitheliae. It is only now that the capillary vessels in the papillae surrounding the porus are enlarged and filled with blood. Signs of discarded horny or epithelial cells ' primarily ' blocking the exit of the duct were not seen. Only occasionally there are a few loose horny cells found in the porus of the sweat-ducts.

No cocci were found in these early stages. Only later on one may find what appears to be staphylococci in the mouth of one porus or another where the tiny vesicle is large or broken and obviously has been several days old before the biopsy was taken ".

[5] The article by J. P. O'Brien (1947) *British Journal of Dermatology and Syphilology*, **59**, 125, should be consulted for an account of this work carried out in New Guinea.

LEPROSY[6]

In 1944, about 1,000 IORs were invalided for leprosy, the numbers having risen steadily year by year. Such figures point to laxity in the medical examination on recruitment. It was generally a period of weeks before a man was boarded out; and the segregation of these patients in the hospital threw an unnecessary burden on the medical and nursing staffs and on accommodation.

SELF INFLICTED INJURIES TO THE SKIN

Nearly all these were examples of deliberate malingering and in the North-Western Army occupied much of the dermatologist's time. The culprits were usually those who had joined the army to be taught to drive a vehicle and, this accomplished, they wished to revert to civil life where they could earn good wages as lorry drivers. *Dhobie* nuts, castor oil beans and the juices of plants, some of which grew in the hospital compound, were the usual agents employed. The malingerer either irritated an intact skin and often presented himself with large oval intensely congested areas on the fronts of the thighs or he aggravated some existing dermatological condition. Admission to the ward of a man with the first type of lesion was not infrequently followed by the appearance of the second type of lesion in other patients, the spread being by example or by personal manipulation for a consideration. Intervention was most likely to occur when the skin was healing and the patient foresaw the prospect of being discharged from the hospital at an early date.

6 See also page 227.

CHAPTER IX

Dysentery

The high incidence of diarrhoea and dysentery cases has been associated with almost every war. The operations in the field involve movements of large bodies of troops under circumstances when hygienic standards cannot be always maintained at the desired level.

The term dysentery is applied to a number of disorders usually characterised by mucus and bloody discharges from the intestines. The bacillary and amoebic dysentery only will be discussed in this account. Reference to diarrhoea will also be made in places.

INCIDENCE

Bacillary dysentery attracted more attention during previous wars than amoebic especially in the Crimean War, the Franco-Prussian War, the South African War, the Phillippines Campaign and the Russo-Japanese War. In World War I it broke out in epidemic form in 1915, among British troops in Gallipoli, Macedonia, Egypt and amongst Indian and British troops in Mesopotamia (Manson-Bahr). The incidence of amoebic dysentery did not exceed 7 per cent. of all clinical dysenteries in the eastern theatres of war, while in France and Flanders it was of minor importance.

INCIDENCE DURING WORLD WAR II

Army in India : The incidence of diarrhoea and dysentery in the Army in India was high during the war. The admission rates per thousand for dysentery, diarrhoea, colitis and hepatitis for the years 1933-46 are given in Table I. Some idea of the incidence of amoebic and bacillary dysentery can be obtained from Table II.

The increase was undoubtedly due to the deterioration of sanitation, mainly inevitable, which took place during the war. In addition, the change in diet, climate, and environment to which large numbers of troops, both Indian and British were subjected, must be considered as factors favouring an increase in the incidence of dysentery and for the increase of amoebic infection as compared to bacillary dysentery. This was a corollary to the fact that the main concentration of the troops shifted from the dry climate of the North-West India to the humid climate in the east, where the incidence of amoebic dysentery was naturally very high.

Burma and South East Asia Command (SEAC) : In the SEAC the dysenteric disorders could be divided into two groups, viz., the non-amoebic majority and the amoebic minority. The amoebic cases, though few in numbers, caused grave concern because of its serious effects on the individual. It was the most important single cause of protracted illness and invaliding.

TABLE I

Incidence (per thousand) of dysentery, diarrhoea, colitis and amoebic hepatitis among IORs and BORs of the Indian Army 1933-46.

Year	Dysentery		Diarrhoea		Colitis		Total		Hepatitis	
	IORs	BORs	IORs	BORs	IORs	BORs	IORs	BORs	IORs	BORs
1933	15·3	24·9	7·9	15·3	0·3	1·0	23·5	41·2	0·6	0·65
1934	13·9	25·5	6·3	14·9	0·2	0·8	20·5	41·2	0·7	0·96
1935	12·2	29·2	5·6	13·9	0·2	0·4	17·9	43·5	0·5	0·46
1936	11·0	24·6	6·2	16·5	0·3	0·9	17·5	42·1	0·6	0·29
1937	12·4	25·5	5·4	16·1	0·4	0·3	18·3	41·9	0·5	0·23
1938	17·2	26·8	7·5	18·0	0·2	0·2	24·9	45·0	0·6	0·53
1939	17·1	29·0	6·3	18·2	0·1	0·6	23·5	47·8	0·5	0·69
1940	22·3	33·0	10·9	25·0	0·7	0·7	33·9	58·7	0·6	0·40
1941	21·0	36·9	23·7	55·4	2·0	1·4	46·8	93·7	0·2	1·03
1942	20·0	50·2	32·7	72·7	3·2	1·5	55·8	124·4	0·5	1·35
1943	16·0	48·8	25·7	43·6	1·9	2·1	43·6	94·4	1·9	1·93
1944	16·2	72·5	20·9	53·2	1·5	1·7	38·6	127·4	7·6	3·98
1945	14·2	72·1	17·0	45·6	1·2	1·1	32·4	118·8	8·9	4·15
1946	13·0	47·6	9·5	28·1	0·9	0·9	23·4	76·6	5·3	2·27

TABLE II

Prevalence of different types of dysentery among IORs and BORs of the Indian Army 1935-46.
(rate per hundred)

Year	Protozoal		Bacillary (confirmed)		Bacillary (exudate)		Clinical (No exudate seen)	
	IORs	BORs	IORs	BORs	IORs	BORs	IORs	BORs
1935	...	10·30	...	41·50	...	23·00	...	25·30
1936	...	10·80	...	46·10	...	22·40	...	20·70
1937	...	10·40	...	49·30	...	19·60	...	20·70
1938	4·56	12·70	61·26	51·30	12·84	17·40	21·34	18·50
1939	3·40	9·10	66·12	61·60	11·91	10·90	18·57	18·40
1940	3·92	8·50	61·69	62·00	13·89	10·40	20·50	19·10
1941	5·43	10·81	44·56	49·69	14·42	10·74	35·59	28·76
1942	5·22	12·99	32·44	38·21	10·88	10·57	51·46	38·23
1943	8·30	17·14	28·70	34·77	10·10	8·59	52·90	39·50
1944	15·70	24·50	37·40	37·10	11·40	10·20	35·50	28·20
1945	17·80	15·26	41·10	54·78	17·60	10·40	23·50	19·56
1946	11·60	9·92	46·40	56·33	23·30	17·72	18·70	16·03

TABLE III

Admissions (rate per 1,000) due to dysentery and diarrhoea on Indo-Burma front—1942-45.

Diseases	1942			1943			1944			1945		
	VCOs and IORs	BORs	All troops	VCOs and IORs	BORs	All troops	VCOs and IORs	BORs	All troops	VCOs and IORs	BORs	All troops
Dysentery amoebic* ...	2·3	64·6	18·07	33·1	130·6	46·98	7·3	14·84	8·80	3·39	12·08	4·83
Dysentery non-amoebic *	50·5	23·2	41·07	0·5	1·4	0·67	32·7	82·60	45·06	10·49	36·54	13·88
Total dysentery	52·8	87·8	59·14	33·6	132·0	47·65	40·0	97·44	53·86	13·88	48·62	18·71
Diarrhoea ...	27·7	41·7	29·14	27·8	77·0	34·56	39·6	91·21	46·41	13·80	26·12	13·66

*Classification not very reliable.

During the retreat from Burma in 1942, a very high proportion of cases of diarrhoea and dysentery occurred among the large number of men, both civilian and military, who trekked back to India by long and arduous routes under extremely unfavourable and insanitary conditions. Since that time a much higher incidence of amoebic dysentery prevailed among troops of the Eastern Army. The incidence of diarrhoea and dysentery on Indo-Burma front during 1942-45 is shown in Table III.

Willatt (1943) observed that amoebic dysentery was a serious cause of incapacity since even a straightforward case, diagnosed on the first day, meant at least twenty-nine days absence from duty. According to Leishman and Kelsall (1944) amoebic dysentery was more than twenty-five times as common in India as in the Middle East. One out of four soldiers from local units, admitted on account of diarrhoea, was, reported to be, suffering from amoebic dysentery. DeMonte (1944) in his series of 1,145 patients, passing mucus with or without blood, at an IBGH for British troops found that some of the infections were severe, many chronic and a large number mild. Laboratory diagnosis was established by microscopic examination. In addition, specimens showing a bacillary or indefinite exudate were cultured. The medium used for primary isolation was rosolic acid medium. The results obtained are summarised in Table IV.

TABLE IV

Analysis of 1,145 cases of dysentery.

Types	Total cases	Cases from which bacillary dysentery organisms were isolated		Cases in which *E. histolytica* and bacillary dysentery organisms were isolated		Cases in which *E. histolytica* only were isolated		Cases in which no pathogenic organism was found or isolated	
		Total	Percentage	Total	Percentage	Total	Percentage	Total	Percentage
Typical bacillary exudate	154	92	59·7	5	3·2	...	...	57	37·0
Indefinite exudate ...	571	143	25·0	6	1·1	99	17·3	323	56·6
No exudate ...	420	...	...	...	...	208	49·5	212	50·5
Total dysentery patients ...	1,145	235	20·5	11	1·0	307	26·8	592	51·7

Of the 1,145 cases examined, 235 were bacillary dysentery, 11 were mixed infections and 307 *E. histolytica* infections. The most striking feature in this analysis was the increased incidence of amoebic dysentery.

The organisms isolated during 1938-41 in all military laboratories in India are shown in Table V. It will be observed that the frequency of the various types of dysentery organisms does not show any marked variations.

TABLE V

Dysentery organisms isolated in all military laboratories in India during 1938-41.

Types	1938		1939		1940-41	
	Total	Percentage	Total	Percentage	Total	Percentage
Bact. dys. Flexner types 1-6 ...	1,254	48·9	1,395	49·6	2,296	52·4
Bact. dys. Boyd types 1-3 ...	450	17·5	468	16·6	498	11·3
Bact. dys. Sonne	457	17·8	474	16·8	672	15·3
Bact. dys. Shiga	236	9·2	298	10·6	573	13·1
Bact. dys. Schimtz	169	6·6	181	6·4	345	7·9

DeMonte further reported that 218 of the 246 strains isolated by him from 303 cases of bacillary dysentery were classified according to Boyd's new classification without difficulty. There were, however, a few mannitol fermenters that were not agglutinated by sera issued according to Boyd's classification. Boyd's strain D-19 was isolated from 13 cases in the series reported. It was isolated in almost pure culture from four patients whose stools were examined within the first four days of onset and who had a typical bacillary exudate.

Payne (1945) found that in forward and base hospitals of Eastern India, amoebiasis was one and a half times as frequent as bacillary dysentery. The stay in hospital for amoebiasis varied from three weeks to several months, the average being 28 days. In bacillary cases, the stay in hospital varied from 7-14 days, usually eight days. Hawe (1945) observed from his experience of cases of intestinal amoebiasis in South India that atypical amoebiasis might simulate any gastro-intestinal disease and should be suspected in all patients from endemic areas.

In the 3rd Indian Division (Special Force) consisting of six brigades, 9 per cent. of the total force were infected with this group of disorders. In May, June and July 1944, the number of cases of diarrhoea in the Fourteenth Army probably exceeded 100,000. There was a tendency for diarrhoea cases to increase during monsoon. The circumstances were favourable for the rapid spread of bacillary dysentery, but it was fortunately limited due to efficiency of the sulpha drugs. A variety of organisms were isolated but there was a general tendency for one or other of the Flexner strains to be the causal organism of particular outbreaks. The proportion of cases of amoebic infection,

reported by the ALFSEA medical units during eight months of 1944, was 20 per cent. of the total admissions for diarrhoea and dysentery. During the period November 1944 to May 1945, dysentery and diarrhoea accounted for a large number of admissions in the Fourteenth Army. But taking into consideration the nature of the campaign, and the toll which these diseases took of manpower in 1944, the incidence was not as large as had been expected.

The total number of cases evacuated during the period (November 1944 to May 1945) was 4,398, i.e., 7·59 per cent. of total admissions—0·12 per 1,000 per day. This total was distributed over the various formations as follows :—

TABLE VI

Dysentery and diarrhoea cases
(ALFSEA, November 1944-May 1945).

Formations	Total cases of diarrhoea and dysentery evacuated	Rate per 1,000 for the period	Daily rate per 1,000	Percentage of total admissions from all causes
IV Corps	1,247	21·25	0·11	6·26
XXXIII Corps	2,182	29·74	0·16	8·09
Army troops	434	12·04	0·08	8·43
5th Indian Division ...	84	6·63	0·05	3·28
11th East African Division ...	349	15·84	0·15	13·06
36th British Division ...	69	4·25	0·20	15·23
19th Indian Division ...	33	1·81	0·26	16·42
Total	4,398	23·11	0·12	7·59

The incidence in XXXIII Corps was generally higher than that of IV Corps while army troops had the lowest rates. This might be due to the fact that army troops were generally more static and able to devote more attention to hygiene.

In the 11th East African Division, cases were spread evenly over all units. The general health of the 19th Indian Division was also unsatisfactory. All units were affected and the cases were spread over the whole period.

There was an outbreak of diarrhoea due to food poisoning in the 7th Indian Division in February 1945 and 86 cases were notified.

The overall figures for the Fourteenth Army show that the admission rate declined from 0·2 per 1,000 per day in November 1944 to 0·1 or less during the latter part of the campaign. Though seasonal and physiographical influences must have played their part, there was no doubt that provision of large quantities of sulphaguanidine for early

use by RMOs and forward medical units was fully justified by the results obtained. Not only were a great number of admissions to hospitals avoided, but also it seemed likely that an early sterilisation of stools had been achieved with a consequent lower carrier rate for dysentery organisms. A large amount of widespread morbidity was undoubtedly due to diarrhoea, mainly water borne in character, which did not necessitate evacuation for treatment. Hill (1946) observed that during the period January to March 1945, the incidence of diarrhoea and dysentery in the Fourteenth Army was 7·6 per cent. while in the L of C Command it was 8·4 per cent. It was noted that 36·5 per cent. of all diarrhoeas were due to amoebiasis. In 1945, the expected annual rise, with the onset of the hot weather, did not materialise. In March, it was 0·11 per mille per day and in May it still stood at 0·1 per mille per day. The incidence rate was one-fifth of that reported in the same months in 1944. The lower incidence was indisputably linked with sulphaguanidine treatment. Every effort was made to treat the cases as far forward as possible and most medical officers, who were provided with adequate quantities of drug, were encouraged to use them in full doses in all cases of diarrhoea.

RAPWI : Towards the end of the campaign, cases of dysentery and diarrhoea were met with among the RAPWI. The incidence of diarrhoea and dysentery amongst RAPWI is given below :—

(i) Prevalence of dysentery among 2,777 RAPWI, sick in the main hospital, at Nakom Paton, in Siam, at the time of liberation :—

Bacillary dysentery	1·0 per cent
Amoebic dysentery	14·0 per cent

(ii) Prevalence of dysentery and diarrhoea among 2,300 RAPWI evacuated by hospital ships from Singapore :—

Amoebiasis, diarrhoea and dysentery ...	8 per cent

(iii) Dysentery and diarrhoea among 1,230 patients admitted to BGHs in Singapore, during one month from 9th September, 1945 :—

Number of cases ...	87
Percentage ...	7·1

(iv) Analysis of 6,864 British POW and internees who passed through Rangoon in September 1945 :—

	Number	Rate per cent.
Cases of diarrhoea and non-amoebic dysentery	60	0·87
Cases of amoebiasis	74	1·08
Cases of infective hepatitis	28	0·41
	162	2·36

It was observed that among the RAPWI from the Japanese camps nutritional diarrhoea due to nicotinic acid or riboflavin deficiency became worse by ordinary diet and firm measures had to be taken to prevent this. Mitchell and Black (1946) found that out of the 577 malnutrition cases analysed, 133 had diarrhoea at some time or other.

At Prachuab Kirikhan, diarrhoea had occurred among 80 per cent. of all POW during their $3\frac{1}{2}$ months stay in the jungle camps. Chronic amoebic dysentery cases were less than anticipated but many were in a quiescent stage. Sub-acute bacillary dysentery, appeared spasmodically. After release a considerable number of the POW and internees had 24 hour diarrhoea, probably due to over eating. All dietary deficiency cases had diarrhoea, mainly at night or in spasms of 24 hour bouts every three or four days and then clearing up. Light and careful diet helped most of these cases. Five deaths occurred after release due to the continuous and uncontrollable diarrhoea in addition to beri-beri.

Pavillard (1946) reported that dysenteries, particularly the bacillary form, were widespread in a Singapore camp. Later, the POW were brought to Siam to work as labourers in the construction of Burma-Siam Railway. Gastro-intestinal disorders were very common in the camp at Wampo. But it appeared that the incidence of bacillary dysentery was decreasing while amoebic dysentery became increasingly common.

Middle East : Fairley and Boyd (1943) observed that the outstanding feature of bacillary dysentery, as seen in the army in the Middle East during 1940 and 1941, had been its mild character. Large-scale epidemics were absent and mortality rates, even in Shiga infection, were not as high as was expected. The standard of sanitation in the field as well as in the stationary camps was at a higher level than in World War I. A safe water supply was maintained without much difficulty. The infection appeared to be mainly flyborne. Mechanisation, motor transport and various anti-fly measures, however, eliminated the chief sources of flybreeding. Troops in the forward areas were instructed to scoop out a shallow hole and cover up the excreta immediately with a layer of loose earth or sand. In more static camps deep trench latrines were provided with flyproof super-structures and with covers which closed automatically. Out of 64,972 cases investigated from August 1940 to June 1943, the dysentery bacilli were isolated from 23,951, majority strain being *Sh. flexneri* (Boyd, 1946). The incidence of dysentery in the Middle East is shown in Table VII.

Bacillary dysentery was predominantly common and Flexner-Boyd group of organisms were more commonly isolated than other types. Analysis of 8,665 cases in which the causal organism could be isolated gave the following results : *E. histolytica* 12·3 per cent.; *Bact. dysenteriae* Shiga 15·8 per cent.; *Bact. dysenteriae*, Schmitz 5·2 per cent.; *Bact. dysenteriae* Sonne 6·3 per cent.; *Bact. dysenteriae* Flexner-Boyd 52·3 per cent.; other non-mannitol fermenters 3·6 per cent.; other mannitol fermenters 4·5 per cent. (Fairley and Boyd, 1943). The seasonal incidence of dysenteries appeared in early and late summer. The incidence of amoebic dysentery was low. In the base areas of Western Desert, a few cases of amoebic dysentery could be seen during the winter but diarrhoea and dysenteries increased considerably in summer. An increase in the incidence of amoebic dysentery during Rommel's first advance (April

TABLE VII.

Admissions (rate per 1,000) due to dysentery and diarrhoea in Middle East, Persia, Iraq and East Africa.

	1939			1940			1941			1942			1943			1944			1945		
	VCOs and IORs	BORs	All troops	VCOs and IORs	BORs	All troops	VCOs and IORs	BORs	All troops	VCOs and IORs	BORs	All troops	VCOs and IORs	BORs	All troops	VCOs and IORs	BORs	All troops	VCOs and IORs	BORs	All troops
Dysentery	..	27·47	22·61	17·25	19·77	15·27	12·97	27·90	12·82	29·99	9·52	27·42	10·28	14·21	9·89	11·06	4·87	10·78	8·83	47·57	12·74
Diarrhoea	..	20·40	16·73	8·08	7·65	7·40	6·08	23·86	6·31	22·74	3·81	20·80	10·16	7·44	10·72	7·25	4·87	7·01	5·55	20·85	7·62

Figures for 1939-41 are not complete.

to September 1941) was attributed to cases and carriers among the troops returning from East Africa.

The dysentery cases seen by Scadding (1944) in the Middle East were mild, and he was of the opinion that there had been a progressive decline in the severity in each succeeding summer. But Boyd (1944) attributed this to early treatment with sulphonamides and not to any change in the virulence of the infecting organism.

In the Western Desert Force, the following difficulties were encountered. Newly arrived troops were unseasoned as regards desert discipline and sanitation. Many units persisted in burying swill and rubbish in inadequate pits even though it was advised that these should be disposed by early and complete incineration with burial of indestructible residues. Local labourers, with a high carrier rate and living in primitive sanitary conditions, were sometimes allowed to camp within the defence perimeter.

BACILLARY DYSENTERY

Classification : World War I gave a great impetus to the further study of the dysentery bacilli and a more scientific classification of these organisms was arrived at, based on biochemical and serological reactions. It was shown that, non-mannitol fermenters of the Flexner-Strong group were heterogeneous, whereas the non-lactose, non-mannitol fermenters of the Shiga-Schmitz groups were serologically homogeneous. The work of Murray (1918), Gettings (1919) and of Andrewes and Inman (1919) made it clear that Flexner bacilli contained at least four antigenic components namely V, W, X and Z and the classification suggested by Andrewes and Inman (1919) for the mannitol fermenters, i.e., Flexner V, W, X, and Y, became established.

Considerable light was thrown on the intestinal disorders of the East, and in India it was found that bacillary dysentery, due to infections with Flexner group organisms was common. Cunningham (1918) showed that in Madras and Bengal about 20 per cent. of the population suffered from ' latent bacillary dysentery ' ; Acton and Knowles (1924) showed that a high incidence of bacillary dysentery existed in Calcutta and demonstrated (in addition to numerous other observers) the importance of the bacillary exudate as a microscopic method of diagnosis. On the military side, Manifold and DeMonte (1928) in Poona, Loganathan in Secunderabad, Little and Large in Meerut and Mhow showed that the incidence of bacillary dysentery of the Flexner type, and not amoebic dysentery, was the more common infection among the cases of dysentery and diarrhoea that could be diagnosed bacteriologically and microscopically. Manifold and DeMonte (1928) produced evidence that there was at least one strain among the mannitol fermenters isolated from cases of acute bacillary dysentery in Poona that had no apparent antigenic relationship to the strains Flexner V, W, X, Z and Y of Andrewes and Inman's classification and that there were probably many others.

The work was continued by Boyd who carried out extensive investigations on the antigenic relationship of different types of *Bact. dys. Flexner* isolated at various military laboratories in India and later in the Middle East. He succeeded in obtaining several new strains of mannitol fermenting, Gram-negative, non-motile bacilli from dysentery cases which differed from the classical dysentery strains in their serological reactions. Boyd (1940) demonstrated that Andrewes and Inman's Flexner strains V, W and Z are valid types and that X and Y are not so. He suggested a new nomenclature for the mannitol fermenting dysentery bacilli that found general acceptance and was adopted by the Indian Army in January 1942. This new classification is given in Table VIII :—

TABLE VIII

Boyd's new classification of the Mannitol fermenting dysentery bacilli and the corresponding old or provisional names.

New	Old
Bact. dys. Flexner I	Bact. dys. Flexner V
Bact. dys. Flexner II	Bact. dys. Flexner W
Bact. dys. Flexner III	Bact. dys. Flexner Z
Bact. dys. Flexner IV	B. dys. India (Boyd) type 103
Bact. dys. Flexner V	Bact. dys. India (Boyd) type P119
Bact. dys. Flexner VI	Bact. dys. India (Boyd) type 88 include the Newcastle-Manchester group.
Bact. dys. Boyd I	Boyd's type 170
Bact. dys. Boyd II	Boyd's type P-288
Bact. dys. Boyd III	Boyd's type D-1

There was one other strain, D-89, which Boyd did not include in his new classification because of insufficient data to incriminate it as a pathogen.

Work was also undertaken on the possibility of identifying new serological types among the non-lactose, non-mannitol fermenters isolated from cases of acute bacillary dysentery. Large and Sankaran (1934) investigated an outbreak of bacillary dysentery in Quetta during 1932-33. He reported that a number of strains morphologically and biochemically similar but serologically different to the Shiga-Schmitz group dysentery bacilli had been isolated. The work was taken up by Sachs (1943) during the years 1936 to 1941. He collected 154 such strains all of which with the exception of two strains from England and three from Egypt were isolated from cases of bacillary dysentery in the different military laboratories in India. From a study of these strains, he found 107 which were different serologically, though similar in their morphological, cultural and biochemical characters to the Shiga-Schmitz group. He classified these strains into 8 new types according to whether they did or

did not ferment arabinose and their ability to produce indole. This classification has not found general acceptance and requires confirmation.

Pathology: Dick (1942) observed the histological pathology in 17 cases in the Middle East, of which six were Shiga and one Flexner. Acute, sub-acute and chronic inflammatory changes were seen in mucous and sub-mucous layers which penetrated into deeper zones following the course of lymphatics and blood vessels. In chronic ulcers sub-mucosa was replaced by a thick layer of granulation tissue. Congestion of blood-vessels and interstitial haemorrhages were seen. Involvement of ganglion in Auerbach's plexus by the inflammatory process caused irritability of colon. Ulceration of colon was seen in sigmoid and rectum. Inflammatory changes also involved the terminal ileum and mesenteric glands. Pre-formed thrombi were responsible for pathological changes in liver and spleen and emboli produced pulmonary infarct and broncho-pneumonia. In the extremely severe cases, liver showed a fatty change with some degree of necrosis. The spleen showed congestion and reticulo-endothelial activity as in septic conditions. An early glomerulo-nephritis was seen in the kidney. The pronounced features had been oedema, albuminuria, presence of granular casts and increased blood urea.

Walther (1942) found azotaemia in Flexner dysentery. He observed that this was due to haemo-concentration, increased protein breakdown and renal failure, which resulted from toxic effect as well as diminished volume of circulating blood.

Complications : Holler (1941) reported that 13 per cent. had complications such as hypo-acidity and gastritis, leucopenia with thrombocytopenia, renal failure, arthritis of larger joints which was not influenced by salicylates and dangers of suppurative appendicitis. Manson-Bahr (1943) further stated that renal failure and peritoneal involvement were the two important complications. In the large series of cases seen by Fairley and Boyd (1943), complications were infrequent. Occasionally, renal failure, intestinal haemorrhage, perforation, peritonitis with localised or generalised effusion, pneumoperitoneum, portal pyaemia, multiple abscesses of liver, haemorrhoids and rectal prolapse were encountered. The systemic complications were peripheral circulatory and renal failure, toxic arthritis, peripheral neuritis, conjunctivitis and iritis, pneumonia, parotitis, petechial and purpuric rashes. Wilke (1943) noted polyneuritis following chronic entero-colitis particularly after an attack of bacillary dysentery. In the series of cases recorded by Leishman and Kelsall (1944) in a military hospital in Western India, arthritis was seen in seven cases, absolute constipation with apparent megocolon in two and a refractory case of Shiga dysentery developed Wernicke's encephalopathy. Three deaths due to bacillary dysentery as terminal event, two in cirrhosis of liver and one in chronic refractory anaemia, were recorded.

Laboratory Diagnosis : The laboratory diagnosis was very much facilitated by the introduction of desoxycholate medium. This medium was of great advantage in the detection of carriers and the isolation of

dysentery bacillus from convalescents and cases in the later stages of the disease.

Treatment: Before the introduction of sulpha drugs, bacillary dysentery cases were treated with rest in bed, light diet and sodium sulphate in one drachm doses repeated 2-hourly up to 6 doses per day. In addition, anti-dysentery, i.e., Shiga serum was administered in severe cases. Among the civilian population, however, dysentery phage was given in addition to the saline and anti-dysentery serum. The efficacy of dysentery phage largely depended upon whether a really potent phage was prepared against large number and varieties of freshly isolated strains of dysentery. The difficulty of preparing effective dysentery phage and the introduction of sulpha drugs militated against the progressive use of this therapeutic agent in cases of bacillary dysentery. Due to shortage of sulphaguanidine and allied compounds M and B 693 was employed as the specific chemotherapeutic drug, for sometime. The results were good. The recommended initial dose was 2 g. followed by a maintenance dose 1 g. 8-hourly till bowel condition appeared to be normal for 2 days. Careful observation of fluid intake and urinary output was considered absolutely necessary to prevent any untoward incident.

In 1944, a directive was issued to treat all cases of any severity with sulphaguanidine and use other sulpha drugs in milder cases. Sulphathiazole was specially recommended and many hospitals preferred to continue its use even when sulphaguanidine became available. The use of succinyl sulphathiazole available only in small amounts, was used for research purposes only.

The drug recommended for treatment of bacillary dysentery was sulphaguanidine since it carried negligible risk. The recommended initial dose of sulphaguanidine was 6 g. (12 tablets) for Indian troops of average size and 7 g. (14 tablets) for British troops. The maintenance dose of 3 g. and 3·5 g., respectively, was used 4-hourly till the number of stools fell below 5 daily, thereafter the same maintenance dose was given 8-hourly till the stools had been normal for 2 days.

The course never exceeded 14 days and in fact most cases required a course of much shorter duration. If sulphaguanidine failed to cure in 5 days, thorough investigation was carried to find out if some other cause such as amoebiasis was continuing the condition and was treated accordingly. Though sulphaguanidine is of low toxicity, a few cases of urinary complications were reported. Hence, fluid intake was ensured during treatment and urinary output of 15-20 ozs. per 8-hour period was secured. The patients were put on an adequate diet at the earliest moment instead of unduly prolonging a fluid diet.

In cases of Shiga infection with much toxaemia, sulphaguanidine was combined with anti-dysentery serum (concentrated refined antitoxin Shiga) starting with an initial dose of 50,000 to 100,000 units. Polyvalent serum was of little value where the causal organism was other than Shiga strain.

Succinyl sulphathiazole was tried in a small series of cases of bacillary dysentery. The impression gained from this trial was that it had no advantages over sulphaguanidine.

The appropriate sulpha drug treatment was initiated as early as possible to protect the bowel wall and prevent the formation and absorption of toxin.

Bulmer and Priest (1943) put forward the plea that classical purgative treatment was scientifically irrational. They abandoned it with a resulting increase in comfort to the patients. Kiloh (1944) thought that salt treatment of dysentery was not rational as it increased dehydration, distorted the clinical picture and altered sigmoidoscopic appearance. An inflamed organ required rest. Hence mild cases were treated by rest, fluid and easily assimilable nutritious diet. Sulphonamides were given in severe cases.

Leishman and Kelsall (1944), however, treated a small series of 32 cases in India, half were given saline and the other half peppermint water draught. Stools became free of blood in 48 hours in the cases treated with saline. In the rest (control group) passage of blood in the stool continued for 3 or 4 days and persistent abdominal discomfort was present.

Willatt (1943) found that in a series of 84 cases treated with saline, an average of 11 days stay in the hospital was required, while in another series of 86 cases treated with sulphonamides, the average number of days in the hospital was eight. Besides a reduced hospital stay, a long period of starvation was not necessary in the sulphonamide treated cases and the rapid improvement which occurred, produced a good psychological effect. The sulphaguanidine treatment was adopted as the standard treatment in the Indian Army.

Cobban and Harvey (1944) emphasised two important points in the treatment of dysentery cases. First an adequate fluid intake should be maintained in the acute stage. For this, intake chart should be kept, bed-head reservoirs of salt and water fitted with rubber tubing and stopcocks are useful and bottles containing glucose, saline and intravenous equipment should be kept in readiness. Secondly, a suitable and adequate diet was necessary during convalescence and the recovery stage. The diet should be adequate in calories, proteins and vitamins. It should provide variations and alternative items, specially for chronic cases, as a suitable type of diet taken over a sufficiently long period is of vital importance for complete healing of mucosa. Preferably it should be prepared in a central diet kitchen by cooks specially trained in invalid cookery. The seriousness of the dehydrated condition was not generally realised by medical officers. Since dehydration favoured the formation of sulphonamide crystals, the administration of large quantities of fluid and alkalies was suggested. To combat dehydration, glucose saline by the drip method was advocated in a large number of cases in which it occurred. Transfusion of serum, saline or blood was given in the most severe cases.

It seems that diagnosis and treatment of chronic bacillary dysentery received proportionately less attention since amoebiasis was found to be

a frequent cause of chronic dysentery in India. Early sigmoidoscopy was found to be the most valuable method of diagnosis. The appearances were by no means always typical and actual ulceration was conspicuous by its absence in the majority of chronic cases seen. It was found that microscopic examination of direct swabs was essential for accurate sigmoidoscopic diagnosis. Sulphaguanidine in the usual doses employed for acute bacillary dysentery often failed to clear up chronic cases. Higher doses and repeated courses were required. Certain cases cleared up with sulphathiazole. The combined use of oral sulphaguanidine or sulphathiazole with 1 per cent. sulphanilamide retention enemata proved successful in some cases.

Chronic entero-colitis often developed as a result of inadequate convalescence in the forward hospitals after attacks of dysentery. Looseness of bowel was the predominant feature and varying degrees of wasting, anaemia and avitaminosis were seen. These cases were often wrongly diagnosed as malarial cachexia or malnutrition. Sulphaguanidine produced prompt response in a good number of cases which indicate that such disorders were of dysenteric or infective aetiology.

AMOEBIC DYSENTERY

Diagnosis : The diagnosis of amoebic dysentery could not often be made at an early stage and results of treatment were poor. It was difficult to carry out an adequate follow-up owing to the transfer of patients from one hospital to another during evacuation and their wide disposal. In peace time amoebic dysentery had a certain relapse rate but during the war it appeared to be an intractable disease. This was probably due to the difficulty of early diagnosis and the disease often being associated with other bowel infections such as bacillary dysentery, infection with haemolytic streptococci and possibly other organisms. In a series of cases investigated in a military hospital in the Central Command, 46 per cent. were found to have mixed infection. Troops living under war-time conditions in India were exposed to a much lower standard of hygiene than in peace time cantonments and consequently suffered from bowel infections in much greater numbers. Their injured mucosa was in an ideal condition for invasion by the amoeba. In case of mixed infection, the presence of amoeba in the stools is often masked by bacillary exudate. Since most of the amoebic lesions are in the rectum or lower sigmoid, sigmoidoscopy revealed a lesion in most cases. Typical amoebic ulceration was often absent but a diffuse hyperaemia with haemorrhagic areas was more common. Amoebae were usually found in a swab or scrape from these areas. Dimson (1943) working in a military hospital at Bareilly observed that in difficult cases of amoebic dysentery with loose stools and occasional trace of mucus or indefinite exudate, sigmoidoscopy should be carried out after six negative fresh stool examinations. Sometimes amoebic ulcers could be seen but a more frequent finding was reddened mucous membrane which bled easily. In persistent cases of diarrhoea, three emetine injections were given as a therapeutic test and continued if response was satisfactory. If all these measures failed, diagnosis of amoebic dysentery was excluded.

In a series of 30 cases of proved amoebic dysentery the average time spent in a hospital before diagnosis was 10·3 days. With sigmoidoscopy, it could be reduced to three days. In acute cases sigmoidoscope was only passed if the diagnosis was uncertain. Many cases labelled as sprue and bacillary dysentery on the presence of exudates, proved to be cases of amoebic dysentery on sigmoidoscopy. Hundred per cent. cases of bacillary dysentery and 70 per cent. of amoebic dysentery had lesions in the rectum. Hence, if the rectum was free, a diagnosis of bacillary dysentery could be excluded. Ninety per cent. of the amoebic cases had lesions in the sigmoid.

Proctitis might give rise to a bacillary exudate in amoebic cases and double infections had always to be guarded against. Sigmoidoscopy is a valuable ancillary measure in the diagnosis of chronic dysentery. It should not, however, be allowed to overshadow the usual clinical sideroom methods in the diagnosis of dysentery. The presence of typical bacillary exudate usually meant bacillary dysentery. It must be added that the bacillary dysentery sometimes excited a quiescent amoebic infection. Primary amoebic dysentery with invasion by secondary organisms might also closely mimic bacillary dysentery.

The GHQ Protozoal Dysentery Investigation Team in 1945 carried out the following procedure for diagnosis (Wright and Coombes, 1945). A careful history of each case was recorded, a thorough physical examination was carried out and a fresh sample of stool was examined on the day of admission. It was found that the amoebae became rounded, immobile and no longer diagnostic within 5-10 minutes of being removed in a swab from an amoebic ulcer. This showed the importance of the stool being examined really fresh. Sigmoidoscopy was carried out as a routine in all cases on the day after admission. Sedatives were found unnecessary and the distance to which the sigmoidoscope was passed depended on the severity of inflammation and ulceration. With this method of investigation, including examination of a swab from bowel mucosa, all cases could be assessed within 24 hours of admission. In doubtful cases stool-examinations were continued for a week followed by a sigmoidoscopic examination. Similar investigation was carried out for another week if the findings were still indefinite.

The material derived from sigmoidoscope was handled as fresh as possible. From the diagnostic point of view swabs were as good as scrapings provided the case was straightforward one of amoebic dysentery. In mixed infections, however, it was considered desirable to swab and scrape the ulcer as quite often the layer of mucus lying on the top of the amoebic ulcer showed a typical bacillary exudate, with few *E. histolytica*, not always easy to spot on account of the heavy cellular exudate. When the top mucus was swabbed away and the ulcer scraped, numerous motile *E. histolytica* could be demonstrated. The use of proctoscope, in case sigmoidoscope was not available, was recommended as examination of lower rectum was all that was necessary. Consequently no difficulty was encountered in acute cases. The commonest lesions that could be seen were small haemorrhages in a normal or

sometimes oedematous mucous membrane and small yellow papules or ulcers with a surrounding ring of infections. The haemorrhages were small, bright red and often flame-shaped, usually of the size of pin's head or larger. The papules and ulcers were about 1/10 to 1/8 inch in diameter. All the three types of lesions and even larger ones such as ulcers 1/2 inch in diameter, round or oval in shape with yellow or red granulating base, large inflamed nodules of the size of a pea with a projecting white tip and irregular even serpiginous ulcers 1/4 inch long with yellow base and red undermined margin, could characteristically be found in the bowel at the same time. The lesions, especially the papules were commonly localised in crops and seen often on the prominent surface of the folds of mucous membrane. In the rectum, inflammation in amoebic cases seemed less superficial and more of the nature of a reactionary oedema. The mucous membrane was thickened and rigid, so much so, that it was difficult to get round the valves. The surface might bleed easily and even appear granular and raw when swabbed. Since bacillary dysentery affects the whole of the large bowel and must, therefore, affect the rectum, it has been observed that if sigmoidoscopy shows a normal mucous membrane while there is exudate in the stools, the infection must be an amoebic one. While this was probably true in most acute infections it was certainly not so in all cases, especially in chronic ones.

It was re-emphasised that the detection of trophozoites of *E. histolytica* in stool depends on freshness of the sample, and ability to keep it as near as possible to the condition prevailing in the bowel, e.g., temperature, reaction, etc. All clean bed pans should be kept in a hot chamber and rinsed out in hot water before being given to the patient. The specimen should be taken directly from the patient to the laboratory and the stool examined at once on warm slides and the preparation kept warm during examination. The heated coin placed on the end of the slide was a make-shift method for the field. A simple inexpensive method described in *Pathology Laboratory Service Current Notes No.* 14, was to improvise a satisfactory warm-stage by pinning a cloth or duster round the draw tube above the coarse adjustment rack, and draping the cloth over the lower part of the microscope and lamp.

Since a stool fouled with urine may have detrimental action on the motility of amoebae, the patient should be instructed not to pass urine in the bed pan. No antiseptics should be used on the pans after they have been warmed ready for use as the presence of antiseptics completely nullifies the examination.

A negative report on one smear from one stool was of little value and if necessary several smears should be made from each stool and several stools examined. The importance of repeated stool examinations is illustrated in Table IX, prepared by the GHQ Protozoal Dysentery Investigation Team.

Even the presence of a bacillary exudate did not exempt one from continuing the search for *E. histolytica.* The presence of double infection was thus another important aspect of the dysentery problem. The very acute onset in some cases with a bacillary exudate followed by the

TABLE IX

The results of repeated examination of stools.

Specimen in which *E. histolytica* vegetative found	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	11th	12th	13th	22nd
Number of cases ...	178	33	18	9	5	8	4	8	3	4	2	3	2	1

discovery of vegetative *E. histolytica* later, pointed to the fact that bacillary and amoebic dysentery were often associated. In some cases chronic amoebiasis of the colon with an abdominal mass in the caecal region might present itself even without dysentery or diarrhoea. Its relation to dyspepsia, even of the upper abdominal type, was less frequently recognised.

Routine stool examination of all cases was considered desirable provided time permitted this, as much chronic ill-health was due to amoebiasis which did not show symptoms of dysentery.

Relapses : Under war-time conditions, the relapse rate was very high in the eastern theatre. DeMonte (1944) reported that 40 per cent. of 318 cases of amoebic dysentery treated in 1943, relapsed again and again in spite of intensive and vigorous treatment. He stated that excepting in the relatively few cases of chronic amoebiasis, emetine had gained recognition as being specific for amoebic dysentery in pre-war days and that its failure in such a large percentage of cases may have been due to : (a) use of war quality emetine ; (b) infection with emetine resistant strains of *E. histolytica* : (c) relapses being not true relapses but re-infections in the ward, and (d) failure of early diagnosis so that when the disease was at last diagnosed and treatment commenced, the condition had already become chronic.

With reference to the first possibility DeMonte stated that the emetine used was the product of a firm of repute and that the hospital authorities had the emetine tested and found it to be 100 per cent. up to standard. As regards re-infections in the ward, opportunities did exist but he did not think that this accounted for all the relapses because he had seen large numbers of trophozoites of *E. histolytica* actively moving about in the stools of patients who had been given 1 grain emetine, daily, for 4 days previously. With regard to failure of early diagnosis DeMonte stated that there were a number of cases that were diagnosed early and instanced one of many cases where *E. histolytica* was first found one month after the first examination of the stools in spite of the fact that every facility existed and every endeavour was made for demonstrating the amoebae in freshly passed stools. This failure to demonstrate the amoebae, was probably due to

very small number of amoebae which microscopy failed to discover. In such cases, he suggested that cultural methods should be tried.

Wright (1945) found that 45 per cent. of the 180 cases treated in 1944, relapsed within 6 months. Leishman and Kelsall (1944) noted that of 333 direct admissions during August 1942 to August 1943, in a military hospital in Western India, 45 per cent. had been treated for one or more previous attacks suggesting that the relapse rate was almost identical with that of BT malaria. On the other hand, severe and resistant cases in bacillary dysentery were uncommon. A certain number of cases originating as amoebic or bacillary dysentery passed into non-specific colitis. Five hundred and forty-three cases were recommended for evacuation to the United Kingdom in 1945 alone because of intractable amoebic dysentery. Anti-amoebic drugs were in very short supply at the time in India. In a technical instruction from the Medical Directorate, India (1944) the need for a fresh outlook was emphasised. It was stressed that initial attack should be regarded seriously and treated whole-heartedly as soon as possible. Greater efforts were necessary for an early diagnosis ; a complete clearance examination was to be carried out at the termination of the treatment and repeated three weeks after discharge from the hospital.

Adams (1945) observed that a number of cases that arrived in the United Kingdom from the Indo-Burma theatre proved refractory to treatment. The causes were either unusually virulent and resistant strains of parasite or excessive dosage with emetine even after it was plainly evident that emetine would not sterilise them. Amoebae became resistant to emetine and less amenable to other available drugs. Manson-Bahr (1945) thought that repeated injections of emetine in successive courses in debilitated patients only served to produce an emetine-resistant strain of *E. histolytica*. Lourie (1945) reported the experimental production of emetine resistant cultures of *E. histolytica*. On the other hand Murgatroyd, (1946) could not find any experimental evidence of drug resistance. Sometimes, when EBI was available, failure of treatment was due to the drug being administered in keratin coated capsules which was not absorbed. Manson-Bahr (1945) obtained success in some resistant cases from India by giving EBI in absorbable form.

Hargreaves (1946) thought that in these refractory cases from the eastern theatre, there was no evidence of emetine fastness. Variation of virulence of different strains of *E. histolytica* was also far from clear. Evidence pointed to the differences in susceptibility in different individuals. It seemed that secondary bacterial infection played an important part in determining the severity of colitis and resistance to treatment. Wright and Coombes (1945) reported that the length of the interval which elapsed between the onset of symptoms and the beginning of proper treatment was directly related to the tendency to relapse. The average duration of the symptoms was six weeks in cases that were cured whereas it was six months in those that relapsed.

TABLE X

Relation of relapse rates to duration of symptoms.

Duration of symptoms	Number of cases	Number of relapses	Percentage of relapses
0–2 months ...	208	11	5
2–4 months ...	23	5	22
4–6 months ...	10	4	40
6–8 months ...	10	4	40
8–10 months ...	...	...	...
10–12 months ...	4	2	50
12–14 months ...	8	4	50
14–16 months ...	3	3	100

In a series of 804 cases seen by Willatt (1943) in Calcutta, relapse rate was 5 per cent. during May to December 1942. Many cases were not re-admitted there and perhaps accounted for the low figure. In a series of 200 cases, 10 per cent. relapsed. In 1 per cent. the relapse was for the second time. Willatt (1943) suggested that cases with more than three relapses should be invalided to temperate climate. Dimson (1943) observed a relapse rate of 35 per cent. In a meeting of the principal medical officers at HQ SACSEA, Tyndall (1945) observed that considerable difficulty was experienced in the control of cases after discharge when they were supposed to report for stool examination after two weeks. Blumgart (1945) advocated the use of an 'amoebic register' for following-up cases in a form similar to that used in syphilis.

Relation to Overseas Service : The GHQ Protozoal Dysentery Investigation Team, investigated the relation of 819 bacillary and 276 amoebic cases to the length of overseas service. The early period of overseas service showed a relatively higher incidence of bacillary dysentery but later amoebic cases increased. It was of interest that the earliest case of amoebic dysentery in this series had been in India for only fourteen days. Recent arrivals in India from the United Kingdom seemed very susceptible to both types of infection. In a series of 200 cases of amoebic dysentery, 64 per cent. had served in India for six months or less. Figures collected from the British troops in Calcutta who had developed amoebic dysentery showed that 67 per cent. developed the disease in the first six months of service in India. In a series of 95 BORs, 22·1 per cent. were found to be infected with *E. histolytica*, 9·5 per cent. had amoebic dysentery and 12·6 per cent. were passing cysts but gave no history of amoebic dysentery. Average loss of manpower appeared to be 26·8 days per man in *E. histolytica* infection whereas it was 2·28 days per man in diarrhoea and bacillary dysentery.

Complications and Sequelae : Payne (1945) noted the following complications in a series of 1,000 cases of amoebiasis in the forward and base hospitals of Eastern India : Mild amoebic hepatitis 50 per cent.; haemorrhage (severe) 0·2 per cent. ; perforation with general peritonitis 0·6 per cent. ; perforation with abscess formation 0·2 per cent. ; rectal granuloma 0·2 per cent. Of the 28 cases of hepatic abscess seen, 20 were among the Indians. The percentage figure was 6·6 per cent. in 300 Indian troops and 1·1 per cent. in 700 British troops. An Indian patient in whom the abscess was secondarily contaminated with *Staphylococcus aureus*, died. Perforation was detected in the caecum in seven cases and once in the ascending colon. Of the two cases of haemorrhage, one died of perforation but the other recovered with emetine injections and blood transfusion. Rectal granuloma cases were treated with emetine and eusol enemata. Amoebic hepatitis with thickened caecum and liver tenderness sometimes closely simulated appendicitis, but sigmoidoscopy revealed typical lesions in 50 per cent. cases.

Hawe, (1945) found perforation in less than 3 per cent. of the severe cases in a military hospital in South India during 1942-44. The bowel was very friable in the acute cases, so much so, that the sutures would not hold. The outlook was hopeless in cases of multiple perforation with grave toxaemia. In cases of sub-acute perforation, abscess sometimes developed insidiously. Considerable difficulty was experienced in distinguishing acute caecal amoebiasis from acute appendicitis. Amoebic appendicitis was an extension of caecal amoebiasis. Since operation was a special risk in caecal amoebiasis, it was contra-indicated unless the cases were complicated with abscess, perforation or obstruction.

McConaghey (1945) reported that an Anglo-Burmese woman who had suffered from amoebic dysentery during evacuation from Burma in 1942, developed a fungating ulcer around anus, spreading forward over the perineum to the posterior vaginal wall. Motile *E. histolytica* were seen in serous exudates and the case was cured with emetine. Hawe (1946) reported existence of amoeboma indistinguishable from carcinoma in six cases. In five cases complete resolution occurred with emetine. In the sixth case, whole colon was diffusely ulcerated. Colostomy was indicated when other methods failed. Cropper (1946) reported amoeboma in the hepatic flexure of a Gurkha aged 23 years who was completely cured with emetine and penicillin. Smyth (1946) noted that amoeboma was sometimes mistaken for carcinoma and left iliac colostomy was performed. Conversely two cases of carcinoma, where rectal digital examination had been omitted, were treated for dysentery. Somervell (1946) thought from his experience in South India that all cases of carcinoma of rectum in tropics should be examined for amoeboma before operation or radium treatment. He reported 10 cases of amoebic disease of rectum and four of amoebic abscess in perineum and buttocks. Naunton Morgan (1946) emphasised the difficulties in differential diagnosis of amoebic tumours of gut and dangers of operation in undiagnosed cases of amoebiasis and bacillary

infection. Amoebic hepatitis and liver abscess were frequent in the Eastern Army and unusual cases such as strictures of the colon, localised peritonitis and amoebic masses were mistaken for carcinoma.

Treatment : Amoebic dysentery before World War II was mainly treated with emetine and the response to treatment was reported to be generally good. Civilians usually sought treatment later in the disease than army personnel, relapses were more frequent and there were a few cases of amoebic dysentery that did not respond to any anti-amoebic treatment. A good number of these chronic sufferers were Europeans, who were advised to proceed to England on long leave. Treatment abroad, on usually the same general principles, was often successful. This led many to believe that such cases were not true relapsing ones and that the frequent attacks of acute dysentery were due to re-infections. As a corollary, it was believed that the chances for re-infection were greater in India than in England. Arsenical compounds like stovarsol and carbarsone were tried and carbarsone acquired a limited recognition as being useful in the treatment of cyst passers. For such cases, emetine 1 grain was administered intramuscularly for 2-6 days if the patient was suffering from an acute attack at the time of seeking treatment. It was followed by carbarsone 0·25 g. in capsules 3 times daily for 10 days, and again repeated after an interval of 10 days in the same dose for further 10 days. Lastly, EBI 2 or 3 grains was given at bed time for 4 successive days.

Yatren enemas were given to such cases. Soon after the introduction of sulphapyridine (M & B 693) a certain number of dysentery patients were treated with that drug, administered orally, but it was found to be ineffective in the treatment of amoebic dysentery. A scheme for the treatment of chronic, relapsing, amoebic dysentery was drawn up and tried during 1940 and early 1941. Emetine, carbarsone, EBI, bowel washes, and M & B 693, 6 g. in normal saline as a retention enema, were all given on the different days over a period of 33 days. The patient was kept in bed during emetine administration. It was considered advisable to give small and easily digested meals that would leave very little fibrous residue, during the period when bowel washes were given. This line of treatment was tried on a few cases with promising results. This was the position of treatment of amoebic dysentery cases up to 1940.

Cameron (1945) observed that prior to 1944, it was a case of 'use what you have in the treatment of amoebic dysentery' in India. This eventually resulted in a course of treatment with 12 injections of emetine hydrochloride followed by an arsenical preparation (carbarsone, stovarsol or amibiarson) if available ; if not by a further course of six emetine injections. Relapses received the same treatment. In order to ensure a thorough standard treatment with the available drugs, a technical instruction was issued in June 1944. The course outlined was, however, a compromise as the necessary drugs were not available in quantities sufficient to meet the needs. It retained six injections of emetine but incorporated chiniofonum retention enemata. Difficulty was experienced in some hospitals, especially in Indian military hospitals, with the

administration of chiniofonum enemata, consequent on the lack of adequate nursing staff. Most hospitals, however, were able to carry out the regimen. As a result of this treatment which was coupled with early diagnosis and tests for cure, better results were obtained. In the middle of 1945, liberal supplies of EBI became available and encouraging reports on the value of diiodo-hydroxyquinoline (diodoquin) were received. Consequently a new standard treatment was initiated by GHQ which was based on EBI as the drug of pre-eminent value. Emetine injections (2 or 3) were permitted only for the alleviation of the initial acute symptoms. The EBI therapy was supported by the administration of oral diodoquin or enemata of chiniofonum and the course was completed with an arsenical preparation for a short period. Emphasis was maintained on the importance of test for cure and sigmoidoscopy on termination of the course of treatment.

The scheme of treatment outlined in the *Technical Instruction No.* 24 issued by the Medical Directorate, GHQ India in June 1944, consisted of 25 days drug therapy by 4 different drugs in overlapping sub-courses.

Scheme of treatment for amoebic dysentery.

Day	1–6	Emetine hydrochloride gr. 1 subcutaneous injection nightly.
,,	5–14	Chiniofonum (Quinoxyl-yatren) retention enemata 2½% or 4% each morning, 250 ccs. to be retained for eight hours.
,,	7–12	Emetine Bismuth Iodide grs. 2 or 3 by mouth on an empty stomach each night.
,,	13–25	Tabs. Amibiarson 0·25 Gm. twice daily after food.
,,	20–25	Emetine Bismuth Iodide grs. 2 or 3 as before.
,,	29–31	Three stools to be examined for clearance.
,,	29–31	Sigmoidoscopy.

Beaton (1945) evaluated the GHQ treatment and three other modifications of it, in a series of 89 cases of intestinal amoebiasis. The modifications were first, diodoquin 2 tablets (0·21 g.) 3 times per day after food in place of chiniofonum retention enemata ; secondly sulphaguanidine 101 g. during the first 5 days concurrently with emetine hydrochloride ; thirdly diodoquin in place of chiniofonum and with the addition of sulphaguanidine as above.

Table XI shows the details of the investigation :—

TABLE XI

Evaluation of the GHQ treatment with three other modifications.

Type of cases	G.H.Q. treatment			GHQ treatment with diodoquin instead of chiniofonum			GHQ treatment with sulphaguanidine			GHQ treatment with diodoquin and sulphaguanidine		
	Number of cases	Number of relapses	Percentage of relapse	Number of cases	Number of relapses	Percentage of relapse	Number of cases	Number of relapses	Percentage of relapse	Number of cases	Number of relapses	Percentage of relapse
Not previously treated ...	23	1	4·3	26	1	3·8	14	...	...	18	...	...
Previously treated	2	1	50·0	6	1	16·7	...	...	...	...	...	...
Total ...	25	2	8·0	32	2	6·3	14	...	...	18	...	...

The cases were followed up for a period of 4 weeks as laid down in the GHQ scheme but the number of cases allotted to each treatment group was small. Bearing these limitations in mind, the following tentative deductions were made. Cases treated with diodoquin incorporated in the GHQ scheme showed a slightly lower relapse rate (6·25 per cent. of 32 cases) than those treated with chiniofonum (8 per cent. of 25 cases). It was, therefore, deduced that the GHQ treatment which included diodoquin was slightly more effective. Recurrence or onset of diarrhoea during the diodoquin course was less frequent than when chiniofonum retention enemata was employed. Since the administration of chiniofonum retention enema requires nursing skill and patience, not always possible to obtain in a busy and overworked dysentery ward and also a fair measure of intelligent co-operation from the patient, it was suggested that the substitution of oral diodoquin would obviate these practical difficulties and greatly simplify the regimen of the GHQ treatment. In the cases treated with sulphaguanidine, along with other anti-amoebic drugs there were no relapses. Beaton (1945) observed that sulphaguanidine deterred the ulcerative process by its direct action on secondary invaders such as dysentery bacilli and streptococci. It might also have an indirect anti-amoebic effect, should a state of possible symbiosis exist between *E. histolytica* and the dysentery bacilli or the intestinal commensal flora.

Since the methods of treatment varied widely throughout the India Command, an investigation was initiated by the GHQ in 1945 to evaluate the various courses of treatment, and if possible to standardise the methods. The members of this investigation team emphasised

the importance of rest and diet in treatment. A careful observation was made on three patients for over a month without giving any specific treatment. They became temporarily quiescent though they relapsed afterwards. Stools became formed and free of amoeba, and ulcers which were not originally severe healed.

In recording the results of investigation with different forms of treatment, a very rigid criterion for diagnosis was followed and included only those cases in which active vegetative *E. histolytica* could be seen. After diagnosis each case was placed in one of the different treatment groups in strict rotation. Details of each course of treatment are shown in Table XII schematically :—

Table XII

Details of courses of treatment for amoebic dysentery.

Group I

Standard Course in use in India.

Emetine grain 1 (Day 1 to 6)	EBI grain 3 (Day 7 to 12)	Carbarsone 0·25 g. b.i.d. (Day 13 to 25)
	Retention enemata-quinoxyl 2½ per cent. (Day 5 to 14)	EBI grain 3 (Day 20 to 25)

Group II

Standard course with sulphasuxidine.

Emetine grain 1 (Day 1 to 6)	EBI grain 3 (Day 7 to 12)	Carbarsone 0·25 g. b.i.d. (Day 13 to 25)
Sulphasuxidine Total 65 g. (Day 1 to 3)	Retention enemata-quinoxyl 2½ per cent. (Day 5 to 14)	EBI grain 3 (Day 20 to 25)

Group III

Standard course with sulphasuxidine and diodoquin and without quinoxyl enemata.

Emetine grain 1 (Day 1 to 6)	EBI grain 3 (Day 7 to 12)	Carbarsone 0·25 g. b.i.d. (Day 13 to 25)
Diodoquin grain 9·6, i.e., 3 tablets t.i.d. Day 1 to 20.		
Sulphasuxidine Total 65 g. (Day 1 to 3)		EBI grain 3 (Day 20 to 25)

GROUP IV

Course with emetine, EBI sulphasuxidine and diodoquin.

Emetine grain 1 (Day 1 to 3)	EBI grain 3 (Day 4 to 15)
Diodoquin grain 9·6, i.e., 3 tablets t.i.d. (Day 1 to 20)	
Sulphasuxidine Total 65 g. (Day 1 to 3)	

By comparison of these different groups of treatment, the value of the addition of sulphasuxidine could be assessed and also it was possible to determine whether diodoquin by mouth was as effective as retention enemata of quinoxyl.

The importance of giving EBI in absorbable form was revealed by the following. Three cases were given EBI tablets and a straight X-ray of the abdomen was taken after 10 hours. In each case, small rounded opacities due to the unbroken tablets could be seen. On the other hand another quiescent cyst-passer taking EBI tablets had diarrhoea on the eighth day and vegetative *E. histolytica* could be seen in his stool. None of these cases showed grey discolouration of stools which should occur after proper disintegration of EBI.

There was evidence of secondary bacterial infection in 41 per cent. in a series of 278 cases, a much higher figure than anticipated. The figure in chronic cases was 42 per cent. while that in the fresh cases was 36·5 per cent. Since drugs of known anti-amoebic potency would have no effect on secondary invaders, it was thought likely that sulphasuxidine and penicillin would be valuable adjuncts to specific treatment. So the following scheme of treatment incorporating penicillin was tried in 92 cases (Table XIII).

TABLE XIII

Course of treatment with penicillin.

Penicillin Total—2 million units (Day 1 to 5)	EBI grain 3 (Day 6 to 17)
Sulphasuxidine Total—65 g. (Day 1 to 5)	Quinoxyl 2½ per cent. (Day 6 to 17)
	Carbarsone 0·25 g. b.i.d. (Day 13 to 22)

Sigmoidoscopy was done before and after penicillin therapy. Marked improvement of the ulcers occurred in every case with penicillin. The cases were divided into two sub-groups, (a) 33 selected cases who had a long history, a number of previous attacks or severe ulceration, and (b) 59 unselected cases. The test for cure employed in this investigation was six stool examinations and sigmoidoscopy after completion of treatment which required a period of additional 10 days stay in hospital. The patient was then sent to a convalescent depot for three weeks on an ordinary diet. He was admitted to the hospital again for a week when three more stool examinations were made and sigmoidoscopy repeated. In case of apparent cure, the patient was discharged and given a printed postcard which he was asked to complete and send back in three months time (i.e., four months after end of treatment) to indicate relapse. Eventually the cards were received from only 88 per cent. of the cases investigated.

The results showed that 96·1 per cent. of all primary cases, 85 per cent. of cases with one previous attack, and only 58·4 per cent. of those with more than one attack, were cured. Table XIV shows the results of treatment in different groups :—

TABLE XIV

Results of the treatment in different groups.

Group	Number of cases	Number of followup cards received	Final result not known	Average number of previous attacks	Average duration of symptoms (in days)	Number of relapses	Percentage of relapse
I ...	60	52	8	0·25	50	4	7·7
II ...	42	38	4	0·25	29	3	7·9
III ...	43	40	3	0·40	57	4	10·0
IV ...	42	39	3	0·86	89	6	15·4
Miscellaneous	20	19	1	0·65	94	3	15·8
Penicillin 'A'	33	29	4	1·8	139	11	37·9
Penicillin 'B'	59	53	6	0·15	50	1	1·9

The results of this investigation showed that problems of amoebic dysentery in India were not therapeutic but diagnostic. If the cases of dysentery could be investigated with adequate care, it was possible to cure a high percentage of them with any one of the methods of treatment outlined. In the various treatment groups without penicillin, the results showed no significant difference when the average number of previous attacks and average duration of symptoms were considered. The addition of sulphasuxidine alone to a course of treatment did not show any improvement. It was found that oral diodoquin was just as effective as the quinoxyl retention enemata. Since the administration of the latter was time-consuming affair, it could be abandoned. In

the penicillin group, only 1 out of 53 unselected cases relapsed. Although not statistically significant, it was quite encouraging. The relapse rate of 38 per cent. in the severe selected cases treated with penicillin was disappointing in view of previous optimistic reports. Of the 11 cases which relapsed in this group, four were subsequently cured with a second combined course. Another case had concomitant infections of malaria, typhoid and kala-azar while in hospital, while two others were treated with a batch of EBI which later proved to be of unsatisfactory emetine content. Taking all factors into consideration, including the remarkable improvement seen on sigmoidoscopy, it was considered that use of penicillin was a valuable advance in the treatment of amoebic dysentery. The scheme of treatment was, therefore, changed. The following two schemes of treatment of primary attack and a standard treatment for chronic (relapsing) amobic dysentery were published in *Medical Directorate, GHQ, Technical Instruction No.* 62. in September 1945.

Alternative scheme of treatment for primary attack of amoebic dysentery.

1.	Days 1 and 2	Emetine hydrochloride grain 1 by injection.
	Days 1 to 20 ... (inclusive)	Diodoquin 5 tablets morning and afternoon, i.e., 10 tablets daily.
	Days 3 to 14 ... (inclusive)	EBI nightly grains 2 for Indian troops, grains 3 for British troops.
	Days 15 to 20 (inclusive)	Amibiarson (carbarsone or stovarsol) tablet 3 daily.
	Days 24 to 26	Sigmoidoscopy and examination of stools.
	Days 41 to 48	Repeat stool clearance tests. If the bowel's mucosa at the first examination appeared unhealthy, sigmoidoscopy should be repeated at this stage.
2.	Days 1 and 2 ...	Emetine hydrochloride grain 1 by injection.
	Days 3 to 14 (inclusive)	EBI nightly grains 2 for Indian and 3 for British troops.
	Days 5 to 14 ...	Chiniofonum (quinoxyl, yatren) retention enemata (1 to 2½ per cent.) 200 to 250 c.c. each morning.
	Days 15 to 20 (inclusive)	Amibiarson (carbarsone or stovarsol) 1 tablet thrice daily.
	Days 24 to 26, Days 41 to 48	As for treatment 1.

Treatment of chronic (relapsing) amoebic dysentery.

Days 1 to 5 ...	Sulphasuxidine or sulphaguanidine 5 g. (i.e. 10 tablets) 6-hourly.
Days 1 to 7 ...	Penicillin 35,000 units 3-hourly.
Days 8 to 27 and follow-up.	Anti-amoebic course 1 or 2 as above.

AMOEBIC HEPATITIS

Mild cases of hepatitis responded rapidly to emetine. These required several courses of emetine over a period of months. To obviate the toxic effects, emetine should be judiciously given at correct intervals and patient must be in bed during treatment and, if necessary,

afterwards as well. Cases of simple hepatitis with mild grades of persistent pyrexia, where all other investigations were negative, responded dramatically to emetine. In an Indian patient with enlarged spleen and liver, chronic malaria was sometimes associated with chronic amoebic hepatitis. Air replacement after aspiration as recommended by Cameron and Lawler (1943) proved of value in finding the size of cavity and assessing response. In a military hospital at Poona one case of amoebic liver abscess was seen which had undiagnosed pyrexia for three months before any localising signs had developed. A quick recovery ensued after two aspirations which were followed by instillation of 3 grains of emetine into the abscess cavity. DeSilva (1945) noted a rise in the incidence of amoebic hepatitis in Ceylon. In a general hospital in Colombo, the number of cases of amoebic hepatitis which averaged 88 in 1929 had risen to 1,279 in 1944. The rise was primarily due to incompletely treated amoebic dysentery. It appeared that alcoholism was not a predisposing factor. Indians were by no means immune to this disease though it mainly affected the Europeans. A tender mass in the epigastrium which appeared like carcinoma of stomach, yielded to emetine therapy. The important diagnostic aids were leucocyte count with a characteristic differential count, skiagram and therapeutic test. The usual localising signs are pain and tenderness over the liver area, and right shoulder: pain especially at night aggravated by movements, hepatic enlargement, signs of lung abscess manifested by spitting of blood or vicarious drainage of anchovy pus and signs of toxaemia. In debilitated and non-reacting persons there may be no fever or localising signs and it may be often mistakenly diagnosed as tropical neurasthenia. Diagnosis depends on moderate leucocytosis, sigmoidoscopy, stool and radiological examinations and therapeutic test. Since the vegetative form of *E. histolytica* are found in liver abscess, hepatic amoebiasis is very amenable to emetine treatment even when there is early pus formation. But the underlying intestinal condition requires combined treatment. If symptoms are not relieved by emetine therapy and pus is suspected, the abscess may be aspirated.

In case of pus being detected drainage is required by a closed aspirator. If repeated aspirations fail, closed suction drainage or open drainage with rib section may be necessary. Even quite large abscesses were found to get absorbed and every case should be given a chance to do so. When aspiration is essential, it must always be preceded by a short course of emetine to get rid of the congested state of the liver so as to prevent dangerous bleeding.

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CHAPTER X

Heat Effects

Atmospheric circumstances unfavourable to life under active service conditions were encountered both in Iraq and India. Much experience has been gained during the recent war and with the dissemination of this knowledge and the general adoption of the simple principles which have been evolved, the heat stroke bogey has been shorn of most of its terrors. Experience was gained at considerable price, for in India in 1942, 2,000 patients suffering from the effects of heat, of whom 75 per cent. were British were admitted to hospitals. Among them, 136 deaths occurred (Marriott, 1943). In Iraq and Persia during the same year, the incidence among British troops was as high as 88·7 per 1,000 and even in Indian troops the incidence was 3·2 per 1,000, giving a total incidence for the whole force of 17·5 per 1,000. Among these cases, the mortality-rate was six times as high in Indians as in British, the figures being 8·87 per cent. for the former and only 1·35 per cent. for the latter.

The incidence of the effects of heat in the India Command and forces connected therewith are set out in Tables I, II and III.

TABLE I

Incidence of heat effects (rate per 1,000) India Command—1939 to 1945.

Troops	1939	1940	1941	1942	1943	1944	1945
VCOs and IORs—							
Heat exhaustion ...	0·2	0·3	0·5	0·5	0·3	0·3	0·6
Heat stroke	...	0·0	0·2	0·3	0·2	0·2	0·1
BORs—							
Heat exhaustion ...	1·9	4·9	6·8	17·5	4·6	6·7	10·5
Heat stroke	0·4	1·2	1·0	2·2	0·7	0·7	1·5

TABLE II

Incidence of heat effects per 1,000 of strength—Indo-Burma Front (Indian, British, East African and West African), 1942 to 1945.

Heat Effects	1942	1943	1944	1945
Heat exhaustion ...	2·39	0·75	1·08	0·51
Heat stroke	0·45	0·24	0·15	0·02

TABLE III

Incidence of heat effects (a), deaths from heat effects per 1,000 of strength (b) and mortality per 100 cases (c)—Persia and Iraq Force—1942 to 1944 (Lipscomb, 1943 ; Hunt, 1944).

Troops	1942			1943			1944		
	a	b	c	a	b	c	a	b	c
Indian ...	3·2	0·3	8·87	0·3	0·03	9·76	0·09	0	0
British ...	88·7	1·7	1·35	15·0	0·3	2·31	2·3	0	0
Whole force	17·5	0·5	2·05	3·5	0·1	2·80	...	...	...

The lessons learnt in 1942 led to greatly improved measures of prevention and treatment in and after 1943. In Persia and Iraq Force the fall in the rates of admission to hospital was dramatic ; the rate for 1943 was only one-fifth of that for 1942.

Another aspect of incidence was its relation to age as seen in British troops in Persia, and Iraq Force. The number of British cases of effects of heat (all types) by age groups in 1943 was ascertained from the special case sheets rendered to the GHQ. The age-grouping of the British troops in the force in the hot weather of 1943, was estimated from the age-grouping in a sample of 20,321 British troops in the force in the latter part of that hot weather (Lipscomb, 1943). From these data the incidence of effects of heat per 1,000 of each age-group was calculated.

Table IV shows how the incidence rose with age :—

TABLE IV

Incidence (rate per 1,000) of effects of heat among British troops (in relation to age-group)—Persia and Iraq Force—1943.

Age group	Incidence
18-29 years ...	12·59
30–40 years ...	17·58
41 years and over ...	26·12

The mean strength of British troops in the force in the hot weather of 1943 was 51,779 and the differences in age incidence are statistically significant.

It will be noticed that almost the whole of the following account of heat effects relates to Persia and Iraq. The reasons for this are that

the incidence was far higher there than elsewhere, heat disorders were relatively more important because of the comparatively low incidence of such potent causes of man wastage as malaria and the dysenteries, and there was exceptional opportunity for special investigations and measures of prevention because, after 1941, there was no direct interference from the hostile forces.

In comparing the figures for Persia and Iraq Force for the different years, it is well to keep the following considerations in mind :—

Climatic Conditions : The prevailing wind in the summer is hot and dry from a north—north-westerly direction, but this hot and dry weather is occasionally interrupted by brief spells, lasting from a few hours up to two or three days, of calm or southern breeze with a relatively high humidity. Such spells are most frequent and prolonged in the plains adjoining the Shatt-el-Arab and river Karun. A chart kept at Basra in 1943, showed close correlation between this type of weather and the incidence of the effects of heat. The actual temperatures were much the same in 1942, 1943 and 1944. Wind records for 1942 are not available but it was the universal opinion that the spells of such weather were exceptionally severe ; wind records for later years show less milder weather in 1944 than in 1943 (Lipscomb, 1943 ; Hunt, 1944).

Acclimatisation : In the hot weather of 1942, the force was strongly reinforced by troops who were not accustomed to great heat, either as individuals or as units, whereas in 1943, reinforcements were few and in 1944, practically none. The reduction in the incidence of effects of heat, however, took place throughout the command and not only in the base areas receiving reinforcements from overseas.

Case Mortality : The apparent increase in the case mortality in the force in 1943 is probably explained by the fact that improved facilities enabled many minor cases to be treated in unit lines instead of being admitted to hospital as they would have been under the conditions of 1942.

Serious outbreaks of the effects of heat were often the result of a combination of unfavourable circumstances. Three incidents may be cited as examples.

In 1942, outbreaks with a high proportion of cases of hyperpyrexia occurred among the unseasoned troops, both Indian and British, within a few hours of their disembarking at Basra ; in fact they accounted for some 80 per cent. of the cases in this area.

Two successive convoys of British troops landing at Basra in July and August had suffered severely from seasickness in the Arabian Sea and prickly heat in the Persian Gulf. After 'standing to' on board the ship a great part of the night, they disembarked at dawn without a meal and journeyed by train to a transit area in the desert where, in the heat of the day, they themselves had to pitch their tents, distribute their drinking water and fetch and cook their rations. Cases of hyperpyrexia began to occur at once and, in one of the convoys, 100 men suffered from heat stroke or heat exhaustion 10 of whom died.

A draft of Indian reinforcements, mostly Bengali seamen for Inland Water Transport units, reached Basra in the early morning and were transhipped from the ocean transport to a river steamer to be landed a short distance downstream. Owing to the lack of co-ordination of movements in the river, this steamer's passage was obstructed by a ferry and she lay in the stream for several hours. The day was hot and still, the decks were overcrowded and there was not enough drinking water. Fifty men went down with effects of heat before the end of the day and six of them died.

Another instance occurred even in 1943. A convoy with armoured vehicles was moving from Iraq to Persia. It was the hottest part of the summer and the first hundred miles of the route were through the plains from north-west to south-east. A following wind, therefore, was to be expected and did, in fact, blow strongly. The men worked on the vehicles till late at night and started early the next morning having had very little sleep and no proper meal. The ice was left behind and something went wrong with the water supply at the first night's halt. On the second day there were 119 cases of the effects of heat, some 15 of which were hyperpyrexial.

The incidents at Basra illustrate the need for thorough preparation and rigid control of arrangements for disembarkation of troops on arrival in a hot country. The measures adopted with all possible speed were dramatically successful as is shown by Table V of actual number of cases of heat effects admitted to hospitals in the Basra area.

TABLE V

*Number of cases of heat effects admitted to hospitals in Basra area.**

Troops	1942	1943
British ...	1,187	174
Indian ...	216	4

Reaction to excessive climatic heat manifested itself in two clinical forms of illness, namely heat-exhaustion and heat stroke. The former, which was much the commoner, was a condition of insidious onset ; there was marked, often extreme, exhaustion and the body-temperature was normal or only moderately raised except in a few long unrelieved cases when hyperpyrexia supervened as a terminal event. Heat stroke, on the other hand, manifested itself as an illness of acute or sudden onset, often without warning (' flash ' cases), and was characterised by very high body temperature, usually actual hyperpyrexia, from the beginning.

In the majority of cases heat-exhaustion is an expression of dehydration due to the deficiency of water and salt in the body. As will

* The total numbers subjected to risk being approximately equal in each year (Persia and Iraq Force letter, 1943).

be seen in the discussion below, there was a proportion of cases, at any rate in Persia and Iraq, which appeared to have a different aetiology. The mechanism of the production of heat stroke is quite different ; it is an acute failure of the heat regulating mechanism of the body.

Before recording the findings of the special investigations concerning heat effects made in Iraq, the condition known as heat syncope should be mentioned. It was likely to develop under unusual exertion in great heat, such as a route march, and was the result of primary dehydration. Dizziness or faintness and great thirst were the chief symptoms. It responded rapidly to rest and liberal drinks.

HEAT-EXHAUSTION

A detailed investigation into the effects of heat was made in a military hospital in Southern Iraq in the summer of 1943. A team was sent out by the MRC (Ladell, Waterlow and Hudson, 1944). This included a study of the physiological changes due to heat in a control group of 24 apparently healthy British soldiers of a base unit in the same area. The changes demonstrated in the control group were as follows.

The blood-pressure fell as the heat increased from a mean of 112/72 to 98/62 mm. Hg. Progressive loss of weight, up to 7 per cent. also occurred. As the heat increased the urine output diminished and this was associated with an increasing blood urea concentration. Concurrently with a rise in the average weekly maximum atmospheric temperature from 106°F. to 117°F., the mean blood-urea of the control group rose from 36·8 mg./100 c.c. to 47·5 mg./100 c.c. In order to maintain approximate water balance, a daily intake of 5½ litres was required at an average maximum temperature of 105°F. but when this rose to 115°F., the demand for water increased to 7½ litres. Analysis of sweat taken from each man during light exertion showed marked individual variation of the salt content, the figures ranging from 0·21 per cent. to 0·32 per cent. ; those men who secreted sweat of higher salt content showed the greater weight loss. As the summer progressed, a degree of exhaustion of the sweat glands appeared and resulted in an increased salt concentration in the sweat of each individual, that is, while normally hypotonic, it deviated towards an isotonic concentration.

Calculations were made of the loss of salt through sweating, which showed that with a sweat salt concentration of 0·21 per cent., 14·7 g. of salt might be thus lost daily, while at 0·32 per cent. the loss of salt might be as high as 22·4 g. This high output was balanced by the absorption of an increased ration of salt amounting to 21 g. daily to which may be added 10 g. derived from foods.

Heat-exhaustion was found to manifest itself as one of the two types, the first (type I) being the result of salt depletion with secondary tissue dehydration, the second (type II) associated with abnormality of sweat secretion following ' prickly heat '.

Heat-Exhaustion Type I : This type was of insidious onset and occurred usually in individuals who secreted sweat of high salt concentration. Initial symptoms were lassitude, headaches and constipation,

which were followed by anorexia, vomiting and cramp in the muscles of the limbs. Such patients looked anxious, ill and haggard, and, while their skins were usually cool and covered with a free perspiration, there was a rise in the internal temperature up to 102°F. in the rectum. The explanation of this paradox probably lay in superficial vasoconstriction associated with a lowered plasma volume.

As a result of salt depletion the osmotic pressure of the plasma and extracellular tissue fluid was reduced. The consequent fall in the plasma volume might amount to 30-50 per cent. while the extracellular fluid of the tissue spaces was found correspondingly reduced to 20-30 per cent. The chloride content of the whole blood was often reduced by about 25 per cent. The reduced circulating volume gave rise to characteristic vascular phenomena ; tachycardia was a constant finding. The diastolic pressure was maintained at a relatively high level by compensatory vasoconstriction ; it was usually found to be 80 mm. Hg. or above, but the pulse-pressure was low, being often less than 30 mm. Hg. The blood-pressure was usually unstable and since the pulse-pressure tended to sink still lower on standing up, syncope often occurred.

The general diminution in the water content of the plasma was reflected in raised haematocrit values and increased concentration of haemoglobin and plasma-protein ; as a sequel to the impaired renal blood flow there was abnormal blood-urea concentration, which might exceed 100 mg./100 c.c. The urine passed in 24 hours was scanty, often amounting to less than 750 c.c., was irritant through its high concentration, and contained less than 3 g. of sodium chloride.

This type of tissue dehydration was not associated with thirst (Marriott, 1943 ; Ladell *et al.*, 1944 ; Copeman and Pugh, 1945). In fact nausea may actually induce the sufferer to refuse the proffered fluid he so sorely needs.

Treatment in severe cases was best initiated by intravenous administration of normal saline, of which 8 to 16 pints might be required, followed by copious draughts of 1/2 strength normal saline made up as lemonade. Retention in a cooled or air-conditioned ward was essential, the criterion for release being the restoration of an adequate urine excretion containing more than the critical amount of 3 g. of sodium chloride in 24 hours.

Hyperpyrexia as a late effect of heat exhaustion was fairly prevalent in Persia and Iraq in the severe summer of 1942, when many unseasoned reinforcements were entering the command. After 1942, when anti-heat measures were more developed and the mechanism of dehydration was better understood, this late hyperpyrexia was hardly ever seen.

When salt-deficiency dehydration was not relieved, it reached a stage of severe and persistent oliguria, or even anuria, with gross nitrogen retention. The sufferer was then too dried up to produce sweat to keep his body-temperature down and after a week or ten days from the onset of the illness, hyperpyrexia supervened. Although the excessive body-temperature could be reduced by physical means, the

dehydration had passed the stage when it could be remedied. No case of heat exhaustion in which this late hyperpyrexia developed was known to recover. In this there was a sharp contrast with the hyperpyrexia of heat stroke from which recovery under appropriate cooling treatment was usually rapid and complete.

The diagnosis in cases suggestive of heat exhaustion could be aided by a simple test estimating the salt concentration of the urine, from which, when the 24 hours urine volume was known, the total salt output could be calculated. An output of less than 3 g. in 24 hours indicated salt depletion.

The test is thus performed: 10 drops of urine are measured into a test-tube with a fountain-pen filler. One drop of 20 per cent. potassium bichromate solution is added. With the same pipette as was used for the urine, 2·9 per cent. silver nitrate is added drop by drop—the tube being shaken after each drop. The end-point is a colour change from yellow to brown. The number of drops of silver nitrate solution equals the number of grammes of sodium chloride per litre of urine (Marriott, 1943). This test was taken into general use in 1942, and was of great value in the differentiation of genuine from spurious cases whose symptoms arose from anxiety or a disinclination to work under uncomfortable conditions.

Heat-Exhaustion Type II: This exhaustion began to appear later in the hot season than the former type, was less clear cut in its symptomatology and not being associated with salt depletion, was far less serious in its implications.

The skin of the central parts of the body showed either active prickly heat, on which secondary infection was often imposed, or the harsh squamous thickening which succeeds it. In either condition sweating was impaired and the affected areas showed a higher temperature than the normal skin (Ladell *et al.*, 1944, *Report*, District Laboratory, Karachi, 1945). This skin dysfunction often led to a small rise in the internal temperature of the body up to 101°F. in the rectum.

Despite diverse symptoms including lassitude, general discomfort and parasthaesia of the extremities the general condition remained good, dehydration did not develop, the urine output remained high with a good salt content and renal function was not impaired.

The sweat-glands appeared no longer able to conserve salt by secreting a very hypotonic perspiration, an average salt concentration of 0·53 per cent. being found in Iraq while a similar series in Karachi showed an even higher figure, 0·7 per cent. compared with 0·3 per cent. found in six controls. Treatment required attention to the skin condition in a cool atmosphere.

HEAT STROKE

As its name implies it is dramatically acute in its onset, either striking its victim down unconscious without warning or taking, at the most, a few hours to develop to a climax. It occurs when the sweating mechanism of the body fails to keep pace with excessive demands made

upon it. Circumstances likely to cause such a failure are very high relative humidity in still or slowly moving air and, rarely, unprotected exposure to a very hot strong wind, for example, a wind of 40 miles per hour at 120°F. In the former circumstances heat loss by evaporation is inhibited, and in the latter the heat is applied more rapidly than it can be lost by evaporation.

The nature of the breakdown of the body's heat regulating mechanism is not clear. Some observers hold that it is almost always a reflex inhibition caused by toxaemia from infection. Certainly if the body-temperature is already raised by such infections as malaria or sandfly fever, the added demands of the climate are likely to be more than the sweating mechanism can compete with. On the other hand typical heat stroke was seen in individuals who had no history suggestive of intoxication and who showed no evidence of infection at the time of the attack or during convalescence.

The influence of air humidity in the aetiology was shown by the higher incidence in the Persian Gulf area where the air is more damp than upcountry. A chart kept at Basra in 1943, showed a general correlation between spells of humid southerly weather and cases of heat stroke, and an even closer correlation between the high night temperatures which prevail during these spells and the actual occurrence of individual cases (Lipscomb, 1943).

The onset of the heat stroke may be preceded by frequency of micturition, but the presenting symptoms are usually extreme restlessness, confusion and mania, which passes within a few minutes into coma. A typical case illustrates the acuteness of the onset. A patient who had been treated for gonorrhoea with an intensive course of sulphapyridine, was discharged to a transit camp at noon. Treatment had evoked some vomiting but the urine was normal on discharge. At 1530 hours he became restless and, abandoning a card game with friends, went into the open. Ten minutes later he was seen to take up a shovel and to make a ferocious attack on a cook who took to his heels and escaped. The attacker pursued him for a short distance before stumbling and falling in a coma to the ground when he was found to have a rectal temperatue of 110°F.

The clinical features of the developed condition are well known, the skin is dry and burning to the touch, the face is suffused, the pulse fast and bounding and the respirations deep. Death may take place rapidly from medullary failure.

Investigation of 12 cases of heat stroke in Shuaiba, Iraq, showed only slight diminution in the chloride content of the whole blood, a negative water balance was never found and the 24 hours sodium chloride output in the urine averaged 4·42 g.

Prompt initiation of efficient cooling measures resulted in rapid recovery but delay of more than one hour progressively reduced the chances of recovery.

A proportion of those who survived an attack of heat hyperpyrexia showed residual organic neurological defects. The syndromes seen

were diverse ranging from dementia, which might be associated with pyramidal tract lesions, to gross cerebellar ataxia, while in a few instances a combination of ataxy with spasticity, simulating advanced disseminated sclerosis ensued (MacAlpine, 1945).

The pathological basis of the ataxia was demonstrated in a British patient who died on the nineteenth day of a period of uninterrupted coma following heat hyperpyrexia. The cerebellar folia showed almost complete disappearance of the large Purkinje cells, this change being uniformly present throughout. Control material from brains of patients who had died in coma from other diseases, as well as brains in which some degree of autolysis had occurred, did not show a similar selective destruction of Purkinje cells.

PREVENTIVE MEASURES IN PERSIA AND IRAQ FORCE

Study of the incidence of effects of heat in Persia and Iraq Force in 1941 and 1942 showed, firstly, that seasoned troops used to a hot climate could operate in intense heat, even to the extent of forced marches in armoured vehicles, with comparatively little ill effect, while men who were not acclimatised and whose commanders were not experienced in man management in such conditions were apt to suffer severely; and also that the worse outbreaks could have been avoided by more forethought and better staff work. Secondly, analysis of case histories indicated that the most important precipitating causes of an attack were fatigue, lack of rest and sleep, inadequate intake of water and insufficient food. Thirdly, that serious developments could usually be prevented by prompt first aid. Preventive measures, were therefore, designed to begin during the voyage to Iraq.

Explicit orders for officers commanding troops and a special medical memorandum for medical officers were issued to Iraq-bound transports at the port of embarkation, lectures on the prevention of heat effects were given before arrival at the port of disembarkation, sun bathing was forbidden and 1/4 oz. extra salt was issued per man daily together with an easily obtainable supply of cool salted drinking water.

Disembarkation was carried out only at night and was so controlled as to avoid heavy fatigue duties. Transit camps were equipped and held ready in every detail to receive newly arrived troops while camp staff undertook all cooking for the first 24 hours after the arrival of any new unit.

Train and road journeys were made as far as possible by night, all convoys being compelled to camp by 11.00 hours. Each convoy was accompanied by a berridge-equipped lorry carrying ice and a generous supply of drinking water, while on all trains special compartment with a trained staff was similarly equipped as a heat stroke treatment centre.

In static camps, an extensive building programme was carried through, special attention being paid to the provision of cool sleeping accommodation for night staffs, while workshops and stores were provided with roofs.

'Water stations' were erected at docks, railway stations, workshops, camps and on main roads to provide shade, cool drinks and shower baths. These stations had a liberal supply of 'Persian Hubs' (4 feet porous earthen-ware water containers) and usually incorporated a cooling screen of tightly packed camel-thorn through which water was constantly dripping.

Provision was made in units to supply a minimum of 12 pints of drinking water per 24 hours for all men engaged on ordinary duties and 16 pints for all men carrying out heavy work in the open. The kit issued to every man included a *chagul* or porous canvas water-bag of about 1/2 gallon capacity which proved an extremely convenient and effective individual method of carrying water except under actual combat conditions.

The salt ration of 1/2 oz. per man per day was augmented by a further 1/4 oz. and drinking water supplies were salted to a concentration of 30 grains to 40 grains per pint, whenever practicable.

Ice was issued on a scale of 1/2 lb. per man per day and a liberal quantity was reserved for food preservation. Alcohol was prohibited until after sunset. The importance was stressed of allowing men to obtain full benefit of sleep during the cool early morning hours and reveille was ordinarily forbidden before 0530 hours.

Amenities were tremendously developed and included canteens, static and mobile cinemas and swimming baths, the last could often be filled with water pumped from local brackish wells.

Specialised medical instruction was given at the GHQ early in the spring of 1943 to selected medical officers from each area, whose responsibility it then became to disseminate their knowledge in their own neighbourhood.

Heat stroke treatment centres were established complete with trained staff in each populated area. Fully air-conditioned wards were provided in each general hospital. Initially the latter accommodated 10 per cent. of the bed strength but by 1945 (owing to reduction of the force) they held 20 to 40 per cent. of the beds (Hunt, 1945).

Finally convalescent depots and leave camps were established in the hills of Persia and Northern Iraq, the policy being to send each man into a cool climate for two weeks each summer.

The benefit achieved by these measures exceeded expectations and an overall reduction in the incidence of casualties from heat throughout the force from 17·5 per 1,000 in 1942 to 3·5 per 1,000 in 1943, speaks eloquently of their efficiency. With the reduction of the death-rate from 1 per 2,000 men to 1 per 10,000 men per annum, the notorious climate of Iraq may be said to have been shorn of its terrors. This striking success was chiefly due to the whole-hearted and unremitting efforts of the commanders at all levels. In reviewing the results of the measures instituted in 1943, the consultant physician of Persia and Iraq Force considered that the greatest single factor in the reduction of casualties was the increased knowledge among non-medical personnel.

It must, however, be remembered that after 1941 the force in Persia and Iraq was not subjected to direct attack by land or air. Forward units in the desert attained a high degree of tolerance to the most severe heat, but the problems of troops engaged in prolonged action in armoured fighting vehicles exposed to sun temperatures of 160°F. to 180°F. never had to be faced. Many of the preventive measures used in Persia and Iraq Force would have been impracticable during actual operations and on lines of communication subjected to serious air attack. The best way, therefore, of minimising casualties from the effects of heat seems to lie in training troops and their commanders how to live and work in it.

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CHAPTER XI

Hill Diarrhoea

Hill diarrhoea has frequently been reported from the Himalayan hill stations of India and from the highlands of Ceylon, Europe and South America. An epidemic of hill diarrhoea occurred in Simla in 1880 affecting 75 per cent. of the European community. Crombie has reported cases in the highlands of Europe and Africa. Manson-Bahr has described the disease in Europeans going from plains to altitudes of 6,000 feet or over above sea-level. During the war troops stationed in certain districts at the foot of the Himalayan mountains also became affected.

AETIOLOGY

Various factors have been associated with hill diarrhoea, such as increased mica content of the drinking water, dysentery or *Salmonella* infection of the alimentary tract, contamination of food and water with termites or a diet lacking in vitamins and amino acids.

Stokes and Raina (1944) reported 332 cases with a syndrome characterised by flatulent dyspepsia, diarrhoea and glossitis with or without anaemia, occurring during 1943-44, at Yol situated 3,650 to 4,500 feet above sea-level in the foot-hills of the Kangra valley in the Punjab. The military personnel at this station were Indian and British troops and Italian POW, and it was significant that almost all the cases of diarrhoea and severe anaemia occurred among Indians and Italians whose protein-intake, specially animal-protein, was much lower than that of the British. Table I shows the approximate daily diet of the three groups : –

TABLE I

Daily diet consumed by the three groups under investigation.

Troops	Protein (animal) (in g.)	Protein (vegetable) (in g.)	Fats (in g.)	Carbohydrates (in g.)	Calories
Indian ...	16·0	90·35	81·31	674·22	4,117
British ...	106·3	36·10	160·84	488·15	4,019
Italian (before 21 June, 1944) ...	54·3	44·75	93·50	623·80	3,777
Italian (after 21 June, 1944) ...	51·2	62·30	73·70	498·68	3,142

Destruction of vitamin B complex by the Indian and Italian method of cooking was suggested as a further aetiological factor. Symptoms of thermolabile B_1 deficiency were, however, never seen and lack of B_2,

though a clinical possibility, was not likely. Drinking-water, which was chlorinated before distribution, was excluded as a cause of diarrhoea on the results of bacteriological examination and chemical analysis. Table II gives the incidence of the disease per 1,000 among the Indians and the Italians :—

TABLE II

Incidence (rate per 1,000) of hill diarrhoea among Indians and Italians.

	1943	1944
Indians	39·30	24·15
Italians	7·70	8·50

From the available evidence the incidence of the disease appeared to be related to rainfall in the monsoon period. Some low-grade infection during the rains was thought to cause the diarrhoea in the first instance and set up a deficiency syndrome in persons with a poor haemopoietic reserve.

In an investigation conducted by Panja (1945) at Darjeeling, which included a USA military rest camp at Jalapahar, the bacteria most commonly isolated were *Paracolon bacilli*, *Newcastle bacillus* and several strains of *B. flexneri*, agglutinable and inagglutinable with standard sera. *Paracolon bacilli* had special features and agglutination experiments suggested some relationship to the bacillus of Schmitz. Their pathogenicity was proved by animal experiment and by the symptoms they produced after oral administration in a human volunteer. Isolated examples of other infections such as pseudo-carolinus were also discovered. In many cases of atypical hill diarrhoea no pathogenic micro-organisms were isolated, although the best media were employed for the purpose. It was considered in such cases that there might be some cause affecting the biochemistry of the alimentary canal. Infection with *Ascaris lumbricoides* and *Ancylostoma duodenale* were very frequent but no more so than in troops stationed in other districts in India where 'hill diarrhoea' never occurred. Amoebiasis was not common enough to be considered an aetiological factor.

The water supply of Darjeeling was tested but could not be incriminated. In the absence of any definite or constant bacteriological agent, investigations were carried out to discover a possible biochemical explanation for the disease. Examination of the gastro-intestinal secretions of diarrhoeic patients living in the Darjeeling climate which combined a low barometric pressure, high humidity and cool temperature, revealed abnormally low amylase and trypsinase values. In the plains on the other hand, such a low finding was absent in diarrhoeic stools whereas in stools from apparently healthy persons from both the places, a similarity existed. This suggested that physical conditions

affecting the gastro-intestinal tract and its secretions played an important part. The reasons are summarised below :—

(i) Diarrhoea occurs in many new-comers to the hill station, usually in the first week after their arrival. It does not persist as a rule for more than a week. This suggests that the system of some new-comers cannot at once adapt itself to the altered physical conditions in the hills.

(ii) Diarrhoea does not occur in the majority of the new-comers. This probably means that the majority of them on their arrival can quickly acclimatise their system to the high altitude.

(iii) Some new-comers eat excessively in the hope of improving their health in the hilly sojourn and getting a good return of their money spent but unfortunately altered gastro-intestinal secretions on account of the altered physical conditions are unable to cope with the excessive eating.

(iv) No pathogenic micro-organisms were isolated from many atypical cases of hill diarrhoea in spite of the use of best culture media. The possibility of virus infection has been suggested. Infection theory in such cases has not been established but the low amylase and trypsinase values in the gastro-intestinal secretions in such cases suggest the idea that this may have some causal relationship with the diarrhoea.

(v) Constitutional symptoms such as fever, malaise, pains and ulceration of gut are absent in such cases and this goes against the infection theory.

(vi) In normal cases in the plains of Calcutta and in the high altitude of Darjeeling, there is practically no difference in amylase and trypsinase values but in diarrhoea cases in Darjeeling the values are 5 to 12 times less than those in Calcutta as shown in Table III below :—

TABLE III

Amylase and Trypsinase values in Calcutta and Darjeeling.

Enzymes	Calcutta units	Darjeeling units
Amylase		
Normal	25–100	20–100
Diarrhoeic	7–50	0·6–10
Trypsinase		
Normal	50–200	50–140
Diarrhoeic	25–100	2–20

(vii) Even in the plains, it has often been found that when a person passes from one climate to another extreme, he is liable to an upset in his gastro-intestinal system.

The above will thus show that a sudden change of climate exerts profound influence on the gastro-intestinal system.

Hill diarrhoea may pass into a full-fledged sprue syndrome as was noted by Rogers in 20 per cent. of his cases of sprue in Calcutta. Similar disorders have been reported elsewhere under comparable circumstances.

Diarrhoea due to deficient diet occurred during the civil war in Madrid and was quickly relieved by nicotinic acid (Jimenez Garcia and Grande Covian, 1942). POW and victims in the concentration camps on poor or starvation rations suffered in the same way (Howat, 1944 ; Adelsberger, 1946).

CLINICAL FEATURES

Typical cases of hill diarrhoea usually suffer from early morning diarrhoea, copious, pale, yellow, liquid stools and borborygmi. Fever and abdominal pain are absent and cellular exudates in the stool are not seen.

In the series of cases at Yol, flatulent dyspepsia was invariably distressing, the abdomen at times being enormously swollen with marked tympanites. A few patients complained of nausea. The motions were large, pale, loose and frothy and the call to stool was often so urgent as to lead to slight incontinence. Diarrhoea continued throughout the day and night and during the acute phase was often aggravated by food. The total fat in the stools was often raised but was usually found to be normally split.

Weakness, fatigue and exhaustion were out of all proportion to the number of stools passed. Sore tongue was common and scaliness of skin was seen in a few cases. Anaemia appeared about four weeks after the onset of diarrhoea, being microcytic in the early stages but becoming macrocytic a few weeks later with anisocytosis and polychromatophilia. Severe anaemia occurred mostly in Indian patients and megaloblasts and normoblasts were occasionally seen. Haemic murmurs were found in a few cases and hypotension was often present. A few patients complained of vague cramps in the calf muscles.

Gastric analysis in this series was almost invariably normal, achlorhydria being seen in one case and hypochlorhydria in three cases only. The van den Bergh reaction was negative and the blood-sedimentation rate normal.

TREATMENT

Since the exact nature of the gastro-intestinal breakdown in hill diarrhoea is still not clear, treatment has necessarily been empirical with rest, warm clothing and a diet with a high protein, low fat and a low carbohydrate content. Stokes and Raina (1944) found that the following initial diet for a few days gave quite satisfactory results :—

Table IV

Initial Diet

		oz.
Skimmed milk	...	48
Citrus fruit	...	8
Liver	...	8
Vegemite	...	2
White of egg	...	2
Tomato juice	...	2
Lime juice cordial, Aerated water, Barley water	...	as required

Whole-milk increased diarrhoea and flatulence and a large quantity of meat was not tolerated in the early stages. Cautious additions to the diet were made, depending on the patient's tolerance for carbohydrates and fats.

Tables V and VI show the intermediate and continuation diets used in Yol :—

Table V

Intermediate Diet

		oz.
Skimmed milk, made into curd	...	32
Lean meat, chicken or fish ...	...	8 to 16
Liver ...	...	8
Vegemite	...	2
*Bread (toasted)	...	4
Fresh fruits	...	16
Tomatoes	...	2
Vegetable puree	...	4
Onions ...	...	2
*Potatoes	...	2
*Sugar ...	...	2
Dal (Indian patients only)		2
*Butter ...	...	1
Eggs (poached, boiled or scrambled)	...	2
Coffee		

The continuation-diet was found satisfactory when the diarrhoea had ceased and the patient could tolerate fats and carbohydrates.

*These items should be introduced with great caution. For Indians who are vegetarians, *paneer* (milk casein) at first made from skimmed milk is suggested. Later *paneer* made from whole-milk can be given. It can be prepared by adding the juice of half a lemon to a pound of boiling milk and is very much liked by Indian troops.

TABLE VI

Continuation Diet

	oz.		oz.
**Atta* or rice ...	14	Onions	2
Bread	4	Potatoes	2
Milk	36	Mutton ...	4
Eggs	2	Liver	8
Butter	1	**Ghee*	2
Cream	1	**Dal*	2
Fruits	16	Vegemite ...	2
Tomatoes ...	2	Sugar	2
Vegetables, green, leafy	4	Tea, barley water, lime juice.	
Vegetables, root ...	4		

Drugs were found to have little effect on the course of diarrhoea. Sulphaguanidine and bismuth salicylate reduced meteorism and the number of stools. Nicotinic acid in 50 mg. doses, five times a day orally cleared up glossitis in a week. Administration of iron and liver by mouth with the special diet improved early cases with anaemia. In cases of anaemia, parenteral liver therapy was undertaken in doses of 2 c.c. intramuscularly on alternate days. In extreme cases blood transfusion was given. A few severe relapses were encountered which ran a protracted course.

Recent reports show that folic acid causes marked improvement in hill diarrhoea and sprue cases. Its influence on fat absorption appears to be similar to that of crude liver extract. The general improvement on folic acid therapy is generally greater than on liver therapy without a correspondingly rapid specific action on the deranged fat absorption. Favourable reports on the use of Vitamin B_{12} in cases of tropical sprue have also been claimed.

CONCLUSION

It appears that advanced cases of hill diarrhoea are indistinguishable from sprue or para-sprue. The disease is not necessarily limited to Europeans in the tropics and to heights of 6,000 feet above sea-level or over. Physical conditions affecting the gastro-intestinal secretions especially amylase and trypsinase may be important factors and require further investigation. The first symptom is diarrhoea which sets up a vicious circle by increasing the vitamin deficiency. Men on diet low in animal protein seem particularly susceptible to the disease, presumably due to lack of haemopoietic reserve.

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*European patients will need suitable substitutes.

CHAPTER XII

Infective Hepatitis

During the past two hundred years numerous outbreaks of infective hepatitis have been described under various names such as epidemic catarrhal jaundice, epidemic jaundice of campaigns, and camp jaundice. The first recorded outbreak occurred at Minorca in 1745. In the American civil war there were 22,509 cases with 161 deaths among the $2\frac{1}{4}$ million men of the Federal Army ; 800 cases occurred in the Franco-Prussian war and 5,648 cases in the South African War.

In World War I a few outbreaks of epidemic jaundice were traced to infection with *Leptospira icterohaemorrhagiae* but others defied investigation. Coincident intestinal diseases in Gallipoli and Macedonia led to the belief of ascending catarrh of bile passages and many were diagnosed as catarrhal jaundice. Martin (1917) observed that some 25 per cent. of British troops serving in Gallipoli and Alexandria contracted infective hepatitis in World War I.

AETIOLOGY

Bamberger (1855) had originally suggested that the initial lesion in catarrhal jaundice (or infective hepatitis as it is now called) was a gastroduodenitis followed by spread of catarrh of the epithelium of bile-duct and that the jaundice was due to obstruction of ampulla of Vater with a plug of mucus. This view was supported by Virchow (1865) and upheld by most physicians till recently.

In World War II infective hepatitis appeared on a large scale among British troops shortly after their arrival in Palestine and Egypt in 1940. Cameron (1943) carried on an extensive study of these cases. Transmission experiments on laboratory animals, e.g., guinea-pigs, rats, mice, hamster, dogs and monkey with blood from cases of infective hepatitis were not successful. An attempt was then made to transmit the disease to human volunteers with inoculation of 1 to 2 c.c. of 'infected' whole-blood serum intramuscularly. All the six volunteers that could be followed up developed jaundice within a period of one to six months. Van Rooyen and Gordon (1942) also tried transmission experiments in a wide range of animals and attempted to isolate the causative agent. Cultural examination of bile collected by duodenal incubation at different stages of the disease during the epidemic in the Middle East Force did not show any pathogenic micro-organism.

Andersen and Tulinius (1938) and Dresel, Meding and Weineck (1944) claimed to have transmitted the disease successfully to experimental animals.

The occurrence of infective hepatitis among American troops in Egypt, Sicily and Italy was also investigated. Special attention was paid (to an agent of the virus groups) which had been recovered from stools, occurring in fatal cases among British and American troops in

Egypt (Paul, Havens and Van Rooyen, 1944). Havens, Paul, Van Rooyen, Ward, Drill and Allison (1945) tried to transmit the disease to human volunteers by the oral and nasopharyngeal administration of infected faeces, and reported a high percentage of 'takes'. These experiments left no doubt that the intestinal oral circuit was at least part of the natural route of the spread of infective hepatitis. MacCallum and Bradley (1944) successfully reproduced infective hepatitis in human cases of rheumatoid arthritis after an incubation period of 27 to 31 days by feeding them with faecal material. Independent observations by Findlay and Willcox (1945) in West Africa showed that 7 out of 18 volunteers developed symptoms of the disease within a period of 17 to 28 days following feeding with faeces emulsified with milk, and filtered faecal material and urine from cases of infective hepatitis. Gauld (1946) traced an outbreak of the disease among American troops in Italy to drinking contaminated well water. These studies indicated the occurrence of the virus of infective hepatitis in human faeces and possibly urine.

Essen and Lembke (1944) demonstrated by electron microscope, the virus of infective hepatitis, a compact polyhedral elementary body of 180μ diameter, which was always found in chorioallantoic membranes of chick embryos and which died following inoculation of bacteria-free filtrates of blood and duodenal washings from sporadic or epidemic cases of hepatitis.

HOMOLOGOUS SERUM HEPATITIS

Findlay and MacCallum (1937) described the occurrence of jaundice in individuals who were inoculated with certain batches of yellow fever vaccine. MacCallum and Bauer (1944) proved that the icterogenic agent was present in the dried pooled human serum employed in the preparation of yellow fever vaccine by injecting this serum subcutaneously into human volunteers and producing jaundice in 59 to 129 days time. The icterogenic agent survived heating at 56°C. in a water bath for one hour and also storage at 0°C. in the dried state for 14 months. MacCallum and Bauer further showed that after the development of homologus serum jaundice, serum from such a case was icterogenic subcutaneously and intranasally to human volunteers. Findlay and Martin (1943) noted jaundice similar to infective hepatitis 56 to 120 days after inoculation with yellow fever vaccine and concluded that the icterogenic agent was a virus rather than a hypothetical toxin present in the human serum employed in preparation of the vaccine. Nasopharyngeal washings from these cases when instilled intranasally into three volunteers gave rise to jaundice. But since no proven secondary cases of jaundice have been described in association with yellow fever vaccine jaundice, droplet spread of the disease appears unlikely.

Cases of jaundice following inoculation with certain batches of yellow fever vaccine have been reported by number of workers, Findlay, Martin and Mitchell (1944); Sawyer, Meyer, Eaton, Bauer, Putnam and Schwentker (1944); Fox, Manso, Penna and Para (1942); Turner,

Snavley, Grossman, Buchanan and Foster (1944) and Badger (1944). Hargett, Burruss and Donovan (1943) used aqueous base instead of serum base in the preparation of yellow fever vaccine in order to eliminate the risk of delayed hepatitis.

The incidence of jaundice subsequent to the administration of serum transfusion or various convalescent sera for therapeutic purposes, has also been described. In 1947 there were 37 cases of jaundice with eight deaths among a group of 109 who were given measles convalescent serum in the United Kingdom. In another group of 36 patients who were given transfusion of the reconstituted dried serum, eight developed jaundice, 10 to 20 weeks later (Ministry of Health, Memorandum, 1943). Havens *et al.* (1945) noted an icterogenic agent in a pool of serum from sandfly fever cases. Beeson, Chesney and McFarlan (1944) noted that the use of convalescent plasma in an epidemic of mumps gave rise to hepatitis two months later. Steiner (1944) observed in North Africa that wounded soldiers developed jaundice (indistinguishable from infective hepatitis) 66 to 114 days after receiving transfusion of blood or plasma. Beeson (1943) and Morgan and Williamson (1943) have also noted jaundice following transfusion of liquid pooled plasma or reconstituted dried serum. Campbell (1946) has reported that two cases of splenectomy at a military hospital in Bangalore were followed within a period of three months by symptoms simulating infective hepatitis. The spleen and the resuscitative measures might have played some part in the aetiology of infective hepatitis since both the patients had received intravenous plasma transfusion. McFarlan and Chesney (1944) reported an outbreak of hepatitis in 44·7 per cent. men injected with plasma.

Hepatotoxic virus was different from that of infective hepatitis in that the incubation period was too long. Post-transfusion hepatitis was much more common in patients admitted as battle casualties than in other hospital admissions. Grossman, Stewart and Stokes (1945) injected gamma globulin as a prophylactic measure in controlled experiments and found a lower incidence of hepatitis in the immunised group but conflicting results were obtained with other batches of gamma globulin. Stokes and Neefe (1945) found that gamma globulin attenuated, and reduced the incidence of infective hepatitis.

Loutit (1944) has noted that a minute dose of 0·1 c.c. intradermally is as effective as a large transfusion of 1,200 c.c. of serum in giving rise to homologous serum jaundice ; hence minute traces of blood left in a syringe after intravenous injection can propagate the disease. Bradley, Loutit and Maunsell (1944) noted that the size, route and the number of injections given did not matter when the pooled serum used was icterogenic.

Oliphant (1944) has reported cross-immunity between homologous serum jaundice and infective hepatitis. Serum from a case of infective hepatitis when injected did not produce jaundice in 10 cases which had recovered from homologous serum jaundice 5 to 19 months previously but 4 out of 11 normal control cases developed jaundice.

He also noted that persons having post yellow fever vaccine jaundice 12 to 18 months previously did not develop it on re-inoculation. Paul, Havens, Sabin and Philip (1945), however, reported apparent lack of immunity between two types of hepatitis as serum collected in pre-icteric phase of infective hepatitis produced jaundice in persons who had recovered from serum hepatitis some months previously. MacCallum and Bauer (1944) using an icterogenic pool of serum could infect a case who had recovered from infective hepatitis six months previously but failed to infect convalescent cases of serum hepatitis. Neefe, Stokes and Gellis (1945) in a series of experiments proved that though there was complete immunity to re-inoculation with the homologous agent, there was none to the heterologous agent. As a result of work sponsored by the Jaundice Committee of the Medical Research Council (1939-1945) and various other workers, it is now known that sporadic catarrhal jaundice and epidemic jaundice are the same and constitute infective hepatitis while post-vaccinal jaundice, homologous serum jaundice and post-arsenical jaundice are also identical and constitute 'homologous serum jaundice'. Both are due to a virus but there are reasons to believe that the two viruses are distinct, though probably related, on the analogy of influenza viruses A and B.

SYRINGE TRANSMITTED HEPATITIS

The incidence of hepatitis in venereal diseases treatment centres as well as in certain diabetes and arthritis clinics in the United Kingdom was high during the war years. Bigger (1943) and MacCallum (1943) suggested that it was being propagated by inadequate sterilisation of syringes during vene-puncture or intravenous injection. Sheehan (1944) noted that there was 50 per cent. incidence of jaundice in syphilitic patients receiving NAB but it was less than 2·5 per cent. in another clinic where syringes were immersed in a strong antiseptic for 15 minutes. In one centre with 75 per cent. of jaundice, 5 patients who were injected NAB with sterilised syringes did not develop jaundice. An isolated community of 34 individuals undergoing arsenotherapy was divided into two arbitrary groups ; eight cases developed jaundice in one group which included a patient incubating hepatitis whereas no case of jaundice developed in the other group. Salaman, King, Williams and Nicol (1944) carried on controlled experiments in two groups. In group I treated by the old technique with imperfectly sterilised syringes, there was 68 per cent. incidence of jaundice whereas in group II in which the syringes were sterilised by dry heat at 150°C. to 160°C. for one hour, the incidence of jaundice was negligible. Laird (1946) noted only one doubtful case of jaundice in a group of 167 patients who were given all their intravenous therapy with careful sterile precautions in a centre having more than 30 per cent. incidence of jaundice. Howells and Kerr (1946) have reported that 20 per cent. of the total admissions for hepatitis received penicillin injections 62 to 157 days previously at venereal diseases treatment centres and concluded that the icterogenic agent present in the blood of individuals was being transmitted to others attending the same clinic due to the inadequate sterilisation of syringes

between individual injections. Turner (1946) has reported several such cases of hepatitis from a BGH in Italy. Darmady and Hardwick (1945) have traced 34 cases to syringe or needle transmission in a group of 182 airmen who developed hepatitis. Marriott (1945) suspected an outbreak of infective hepatitis as having been caused by an infected syringe used in giving cholera vaccine. Leishman and Kelsall (1944) observed that out of 367 cases of hepatitis admitted to a base hospital in Western India, 42 or 11·4 per cent. were receiving antisyphilitic treatment.

It was soon apparent that in the production of post-arsenotherapy jaundice in the venereal diseases treatment centres, arsenic preparations *per se* played little or no part and jaundice developed equally in patients receiving penicillin and other preparations, e.g., bismuth or gold (Hartfall, Garland and Goldie, 1937 ; Kulchar and Reynolds, 1942). MacCallum (1945) reported the presence of an icterogenic agent in the sera of two post-arsenotherapy jaundice cases by transmission to volunteers by subcutaneous injections. Attempts at transmission with naso-pharyngeal washings from induced cases proved unsuccessful whereas a suspension of faeces from one patient when sprayed into or drunk by volunteers did not result in jaundice.

In any particular case of syringe-transmitted hepatitis, the icterogenic agent may be the virus of infective hepatitis or of homologous serum hepatitis depending on whichever agent, the source of infection was incubating in his blood at the time. In order to eliminate its risk, adequate dry heat sterilisation of all syringes and needles was recommended (Ministry of Health, Memorandum, 1945).

MALNUTRITION AND INFECTIVE HEPATITIS

Nutritional deficiency is now definitely established as an important causative factor in the production of cirrhosis in Indian adults and children as also in Javanese, Chinese, Japanese and South Africans. The important factor common to them is the poverty which compels them to subsist on an unbalanced diet composed of limited amount of cheapest food. This is supported by the production of changes in the infant rat liver akin to those of infective hepatitis on a diet low in proteins (Wahi, 1949). It is, therefore, conceivable that in these countries, the virus of infective hepatitis gives a severe blow to an already impoverished liver.

INCIDENCE AND DISTRIBUTION IN THE EASTERN THEATRE

The disease in a sporadic form appears to have a world-wide distribution. During World War II it occurred in an epidemic form in the Allied forces in the Middle East, in Central Mediterranean Force, in Sicily and Italy specially among the Canadian (Dickson, 1945) and New Zealand troops, as also among the German troops in Northern France, Belgium (Dietrich, 1942) and Norway (Stuhlfauth, 1941 ; Gutzeit, 1942).[1]

[1] See also *Medical Research in War.* Report of the Medical Research Council for the years 1939-45, London. His Majesty's Stationery Office.

In India, Burma and Ceylon the disease was sufficiently prevalent to constitute one of the common reasons for admission to the medical wards. One large BGH in Poona where the total number of infectious disease patients admitted was 1,254, treated 992 cases of this disease in 1942-43 or 10·8 per cent. of the total admissions during the period. Infective hepatitis was the third most common disease in this hospital over a 12 months period. Another BGH in Calcutta admitted nearly 300 cases in five months (Seward, 1943). The 81st West African Division fighting in the Kaladan Valley on the Indo-Burma front reported 470 cases during their second campaign in a period of three months in the last quarter of 1944 (Quarterly Report, 1944). Infective hepatitis constituted the highest incidence of any single disease in these series.

When the Allied forces moved into Burma, Stokes and Miller (1947) reported on a number of cases that occurred during the period 1945-46.

Tables I, II and III below prepared by Stokes show the absolute monthly incidence of infective hepatitis in North and South Burma, the total population at risk and the rates per 1,000.

TABLE I

Monthly incidence of infective hepatitis.

Months	South Burma				North Burma				All Burma			
	B	I	A	T	B	I	A	T	B	I	A	T
July ...	119	201	7	327	75	162	1	238	194	363	8	565
August ...	112	154	0	266	74	117	9	200	186	271	9	466
September ...	31	108	2	141	14	51	6	71	45	159	8	212
October ...	41	119	0	160	7	29	0	36	48	148	0	196
November ...	31	81	9	121	10	30	2	42	41	111	11	163
December ...	21	73	5	99	3	15	7	25	24	88	12	124
January ...	10	64	12	86	Not available			22	Not available			108
July-January ...				1200				634				1834

(B=British ; I=Indian ; A=African ; T=Total).

TABLE II

Total population at risk.

Months	South Burma	North Burma	All Burma
July ...	172,500	67,100	239,600
August ...	214,500	64,500	279,000
September ...	193,300	62,300	255,600
October ...	157,900	63,700	221,600
November ...	151,300	68,700	220,000
December ...	147,100	55,900	203,000
January ...	134,800	61,800	196,600

TABLE III

Rates of infective hepatitis per 1,000 of population at risk.

Months	North Burma	South Burma	All Burma
July	1·89	3·55	2·33
August ...	1·23	3·22	1·70
September ...	0·78	0·98	0·83
October ...	1·01	0·57	0·88
November ...	0·80	0·60	0·74
December ...	0·67	0·45	0·61
January ...	0·64	0·36	0·55

In Ceylon the disease occurred in a mild sporadic form but there appeared according to Jayawardene (1945) to be a slight increase in the number of cases among Ceylonese troops in 1943-44; he found jaundice forming 1·12 per cent. of total admissions to his hospital. A large scale outbreak was reported by Kalra (1947) in an Indian labour unit stationed near Trincomalee in Ceylon where 451 cases occurred in nearly 1,200 people at risk, i.e., a contagion index of 37·5 per cent. which is unusually high for this disease.

Sporadic cases of infective hepatitis occurred throughout the year. Table IV gives the incidence in ratio per 1,000 in the Army in India during 1938-46.

TABLE IV

Incidence (rate per 1,000) of infective hepatitis in the Army in India—1938-45.

Troops	1938	1939	1940	1941	1942	1943	1944	1945
Indian	0·6	0·5	0·1	0·3	0·3	1·0	6·2	7·6
British	0·7	1·1	0·4	0·5	3·8	18·5	29·6	20·9

A number of small outbreaks also occurred, such as at Hoshiarpur in the autumn of 1942, among troops under the control of Burma Army where 200 cases were reported, another at Ahmednagar in April-December 1943 where 380 cases were admitted to a BGH and another outbreak in local units in Kirkee, Dehu and contiguous areas where 126 cases (46 officers) occurred in the last quarter of 1944. A small series of 74 cases of infective hepatitis during the autumn of 1942 was also reported. Sporadic cases with occasional fatality were also reported from other areas of ALFSEA, such as Singapore, Siam and French Indo-China. Epidemics have also been reported from an American naval base hospital in South Pacific (Simpson, Powers and Lehman, 1943) where 320 cases were admitted in 1942-43.

EPIDEMIOLOGY AND SPREAD OF INFECTIVE HEPATITIS

The Jaundice Research Team sponsored by the MRC reported that a virus was excreted by patients suffering from infective hepatitis. The clinical and epidemiological observations show that infective hepatitis may sometimes be an excremental disease distributed by flies and water, though there was no evidence of the spread of infection by water, milk or food.

Kalra (1947) in an outbreak in an Indian labour unit in Ceylon traced the infection to the drinking of the polluted water from a nearby stream which was also used for ablution purposes. Besides the poor sanitation, overcrowding in tents, hard physical labour and long hours of exposure to sun were also causative factors. Kirk (1945) from a study of the possible factors in an epidemic among New Zealand troops in the Alamein line in August 1942, concluded that the spread was by flies from human excreta.

McFarlan (1945) on the other hand has observed that the disease is spread by contact, and the respiratory tract is the chief source of infection though faeces may be a source in some epidemics. Other factors, such as climate, physical stress, inadequate diet, alcohol and absence of previous exposure to the disease, however, increase susceptibility to hepatitis.

The two series of 'contact infection' and 'chain spread of infection' illustrated by Cameron (1943) indicate the contagious nature of the disease. Spooner (1943) failed to establish a 'case to case' infection in many cases that occurred in Egypt in 1942. In the series of cases reported from Calcutta, the majority of patients when interrogated reported the occurrence of jaundice in others in their unit. Hunt (1944) from a study of more than 1,000 cases has observed that droplet infection does not account for all cases. There were no cases among the staff of a hospital on the medical side whereas there were a few infections among the surgical staff which could be traced to contact with blood and infected syringes.

The world-wide distribution of the disease makes insect transmission as its cause unlikely. The experiments by Cameron (1943) excluded bed-bugs as a vector of the disease.

SEASONAL INCIDENCE

Though sporadic cases of the disease occur throughout the year, the highest incidence in India was in autumn. It was noted that there was higher incidence of infective hepatitis in British officers serving in India during the period July-October than at other periods (Marriott, 1945). This was also true in respect of the Middle East countries where the dysentery season each summer, with its fly menace and lowered sanitary conditions, was followed by the outbreak of jaundice in the autumn.

In the cases reported by Kalra (1947) from Ceylon the epidemic started in October and the peak of incidence was reached in January. Stokes and Miller (1947) in the series of cases reported from Burma, noted the highest incidence of the disease in July but it continued up to January when the maximum fatality rate occurred. In the series of cases in the West African Division from Kaladan valley, the highest incidence was during the period October to December.

IMMUNITY OF LOCAL INHABITANTS

Jaundice occurs fairly frequently among Indian children but is not seriously regarded. The lower incidence of infective hepatitis among Indians may be due to an immunity acquired in early life. The occurrence of the disease in childhood may have some connection with the high cirrhosis rate seen in young adults.

Cameron (1943) also suggested that the civilian adult population of Palestine acquired an immunity to this disease as it is an endemic disease of childhood. But the British and Allied troops who poured into Palestine and other Middle East countries during World War II acted as a virgin soil for the virus which was ubiquitously distributed throughout the Mediterranean countries. European Jewish immigrants to Palestine also behaved in a similar manner (Btesh, 1944) apparently due to their lack of immunity. Dixon (1944) noted that the attack rate in the Malta garrison was 13·87 per 1,000 among British troops whereas it was 0·24 per 1,000 among the Maltese and that new troops were most liable to attack.

The existence of sub-clinical attacks of infective hepatitis without the occurrence of jaundice has been recognised. According to Van Rooyen and Kirk (1946) the prevalent form of gastro-enteritis popularly known as 'Gyppy tummy' or 'Malta tummy' are examples of sub-clinical form of this disease which confer immunity to subsequent infection.

Completely symptomless cases of hepatitis may also exist as was shown in a nursery outbreak by Pollock using Hunter's test for bilirubin in the urine of contacts (Medical Research Council, 1939-45).

INCUBATION PERIOD AND PERIOD OF INFECTIVITY

Numerous instances of 20 to 40 days interval were seen between the onset of illness and contact with the infected person in the outbreaks that occurred in certain units of the British Army in Sicily. Cameron (1943) arrived at a tentative minimum incubation period of 32 days from a study of contacts and chains of cases of infection among the troops in Palestine.

In the epidemic reported from Ceylon the disease occurred in three successive waves of increasing magnitude whose peaks were regularly spaced at an interval of 18 to 22 days which suggests the probable incubation period of the disease. The incubation period is reported to vary from 20 to 40 days or about one month. The cases

appear to be most infectious in the pre-icteric stage. As some cases of hepatitis can occur without icterus, it is apparent that isolation will not prevent, though it can reduce, the spread of infection. According to Cameron (1943) the study of hospital incidence strongly suggests that infection may spread, during part of the incubation, pre-icteric and portion at least of the icteric stages.

SUSCEPTIBILITY OF OFFICERS

A striking phenomenon in jaundice in the services was the high incidence rate in officers and flying personnel as compared with other ranks and ground staff. The cause of this remained unexplained. Regarding the incidence of the disease in the Army in India, the incidence rates in the British service officers were much higher than IORs as will be evident from the following figures in ratios per 1,000 for hepatitis (other than amoebic) during the year 1942.

TABLE V

Incidence of Infective Hepatitis in the Army in India during 1942.

	Ratio per 1,000
British officers (British service)	12·5
British officers (Indian service)	6·1
BORs	3·8
VCOs and IORs	0·3
NCs(E)	0·3

MORTALITY

In the India Command, during the period January to July 1944, there were 18 deaths from infective hepatitis among VCOs and IORs whereas there were four deaths among BORs from the same disease. This higher mortality in Indian subjects was undoubtedly a measure of their lower protein intake and is in line with the relatively high incidence of 'spontaneous' cirrhosis of the liver among South Indians. This high incidence of mortality in Indians is supported by Lucke (1944) and Witts (1947). The incidence of jaundice was five times as high in the British troops as in Indian troops but the mortality was just the reverse. This difference was also noticeable in the epidemic amongst the civilians. Wahi (1951) found an overall mortality of 22·7 per cent. in Indian civilians. An important finding in his cases has been the high incidence of mortality amongst females (43·2 per cent.) as compared to 7·8 per cent. amongst males. This was probably due to complicating pregnancy. Besides the action of female sex hormone, it is suggested that deterioration of nutritional deficiency in pregnancy has a bearing on the course of the disease.

The mortality figures based on 34 fatal cases of infective hepatitis reported by Stokes and Miller (1947) from South Burma during the

period between 1 July 1945, and 30 July 1946, was 2 per cent. The 34 fatal cases in this series comprise 17 Indians, 9 Africans, 7 British and 1 Japanese ; the majority appeared to have acquired their infection in Rangoon. A striking feature of the series was the rapidity with which the disease progressed to complete the destruction of the liver parenchyma. Seven patients died within 10 days after appearance of the first symptoms, a further 14 cases between 10 and 19 days from onset. In the fulminating cases jaundice only developed terminally and in two cases it failed to develop at all.

The mortality rate was low in cases from North Burma and other theatres of the war. Stokes and Miller (1947) after a consideration of various factors involved concluded that a locally virulent strain of the virus of infective hepatitis was at work in South Burma. From epidemiological resemblances to influenza, they suggested that the unusually severe form of the disease could be attributed to the local strain of the virus assuming a virulent form.

PATHOLOGY

A lobular necrosis of central type and replacement fibrosis in the outer zones of lobules was found by Propert (1938) in a fatal case after administration of measles convalescent serum. Iversen and Roholm (1939*a*, *b*) described a diffuse hepatitis comprising destruction of trabecular structure of lobules and degeneration of liver cells in sharply defined foci of variable size together with mononuclear cell infiltration in periportal areas and around central veins in cases of acute epidemic hepatitis (catarrhal jaundice) basing their observations on 'aspiration biopsy' of liver. They further reported an increase in number and thickening and collegenisation of reticulin fibrils around central veins and also around periportal spaces. The hepatitis usually resolved leading to slight or moderate increase in fibrous tissue which when considerable resulted in cirrhosis. Cameron (1943) concluded from observations on four fatal cases of acute hepatitis and biopsy material from a non-fatal case that generalised infection damages blood vessels leading to haemorrhages and especially leads to liver damage and necrosis similar to that described by Iversen and Roholm (1939*a*, *b*). Microscopically the cut section of liver showed a finely granular appearance in two cases and an irregular pattern of reddish-pink and yellow areas in one case. The microscopic appearances were those of sub-acute necrosis (yellow atrophy) in varying stages. Increased cellularity with lymphocytes and mononuclear cells in portal tracts and hyperplasia of reticulin fibrils around central vein as well as in portal tracts were seen. There was no abnormality in biliary tract but two cases showed extensive haemorrhages. Markoff (1944) concluded that the virus of infective hepatitis was capable of producing generalised capillary damage with varying organ localisation.

Dible, McMichael and Sherlock (1943) reported from biopsy studies that the histological picture was the same in infective hepatitis, post-arsenotherapy jaundice and homologous serum jaundice. Degeneration

of liver cells was most marked in the centres of the lobules and appeared to spread outwards whereas infiltration of leucocytes and histiocytes was most prominent in the portal tracts and spread inwards. The essential lesion was that of an acute hepatitis and there was no evidence of any biliary obstruction or fatty change. A 'zonal type' of change with periportal cell infiltration predominating, occurred in early mild cases and during recovery, whereas a 'diffuse type' of change with a more pronounced cell necrosis and more widespread infiltration was marked in the severe cases. The ultimate result might be a fatal issue from acute or sub-acute hepatic necrosis, a classical cirrhosis when the course of the disease was prolonged or just a residual fibrosis in mild cases which completely cleared up later. Complete recovery was possible even with the most severe lesions, the process of regeneration being assisted by preservation of the reticulum frame work. Similar observations were made by Lucke (1944) from post-mortem examination of 125 cases of post yellow fever vaccine hepatitis.

In most cases the liver had decreased in size but in more chronic cases the liver was larger showing tumour like masses of regenerating parenchyma which did not show normal lobular structure. In some areas degeneration occurred in the regenerated masses from ischaemia and bile stasis.

The frame work of lobules remained unaltered and was outlined by proliferating bile-ducts which appeared to be capable of forming new liver cells. The liver parenchyma was completely destroyed in some areas whereas in others there was relative sparing of the periphery of the lobules. Lucke (1944) observed that the lobular architecture was preserved and reticular frame work left intact. Small patches of hepatic parenchyma were missing from the centre of lobules in two early convalescent cases. But there was no evidence to show any permanent damage to hepatic parenchyma and restoration of liver tissue was practically complete.

Stokes and Miller (1947) have reported from South Burma on 34 fatal cases of infective hepatitis in which the recognised complication of hepatic necrosis occurred. In the acute cases there were haemorrhages of wide distribution, pulmonary, subpleural, subpericardial, mesenteric, sub-arachnoid, myocardial, intestinal and renal pelvis. The cardiac haemorrhages had a curiously constant distribution among the branches of the left coronary artery, along the line of left auriculo-ventricular junction and below the aortic valve. The liver was smaller than normal and sometimes so haemorrhagic that necrosis was not obvious at first sight. The liver from one acute case had the appearance of chronic venous congestion. Histological examination revealed a widespread necrosis which always started centrally and spread outwards. This characteristic led to a spurious resemblance to a nutmeg liver in one case. There was often cerebral oedema.

In the sub-acute cases diffuse haemorrhages were present. The liver was studded with nodules of regenerating hepatic cells, the fibrous stroma was increased but the rest of the substance was necrotic. No

normal architecture was discernible. Histological examination revealed bile-duct proliferation and formation of new parenchymatous cells arranged in large formless pseudo-lobules commonly showing secondary necrosis. Patchy phlegmonous inflammation of the gut was sometimes seen with gross oedema and cellular infiltration of the submucosa, the gut being distended above those patches. Inflammatory and necrotic changes were observed in the pancreas and adrenals. None of these cases of hepatic necrosis reported by Stokes and Miller (1947) had the high leucocytosis and urinary changes of Weil's disease nor had they any clinical resemblance to yellow fever. Leptospira could not be demonstrated and hepatic pathology was different from leptospirosis while characteristic 'Councilman bodies' of yellow fever were not seen in any case. The possibility of poisoning by arsenic or any other chemical was also excluded. Taylor (1943) has noted that two cases of epidemic jaundice were indistinguishable from acute yellow atrophy at autopsy.

CLINICAL PATHOLOGY

Assessment of various laboratory tests by the jaundice committee of MRC showed that latent cases could be detected by Hunter's test for bile in the urine whereas bromsulphalein excretion test and erythrocyte sedimentation rate were valuable diagnostic aids in the pre-icteric stage. Bromsulphalein excretion test was the earliest constant abnormality found. Biopsy of the liver, though of much help in controlling research studies, was found to be too dangerous as a routine diagnostic procedure.

The histamine test introduced by Klein (1931) consists of the intradermal injection of 0·25 c.c. of 1 per cent histamine solution into light coloured area of skin. This was an effective test for detecting latent jaundice cases in which the centre of the wheal became yellow (Cameron, 1942). The van den Bergh reaction was found to be biphasic in the early and late stages but a direct response was obtained at the height of icterus. Phosphatase activity of the serum was increased but a return to normal was an index of cure of hepatitis. Blood sedimentation rate was within normal limits in majority of cases (Cameron, 1942). Wood (1945) found erythrocyte sedimentation rate could distinguish infective hepatitis in which it was below 10 mm. in one hour from malaria in which it varied from 20 mm. to 60 mm. in one hour. Bleeding and coagulation time were within normal limits. Turner *et al.* (1944) concluded that the rate of correction of prolonged prothrombin clotting after vitamin K therapy was the best single guide in making prognosis in hepatitis following yellow fever inoculation.

Liver Function Tests : Impairment of liver function could be detected by the various liver efficiency tests, e.g., laevulose tolerance test (Cameron, 1942). Taylor (1943) found laevulose tolerance test in 12 mild cases to be normal. As regards hippuric acid synthesis, Pollock (1945) reported that it returned to normal by the time jaundice appeared. He also found normal values in convalescent cases with raised serum

bilirubin, whereas Sherlock (1946) found low values in conditions in which liver damage could not be detected by biopsy or other functional tests. However, Rennie (1945) considered it to be an effective test for liver function. Gordon (1943) has also obtained evidence of liver damage in infective hepatitis with oral hippuric acid test. Dick (1945) found that the cephalin cholesterol flocculation test of Hanger was positive early in the disease. It was also a measure of the severity of the disease and helped in assessing prognosis. A positive ‘thymol turbidity test’ introduced by Maclagan (1944) was twice as common in infective hepatitis as in arsenotherapy hepatitis and could distinguish these conditions from obstructive jaundice. Higgins, O'Brien, Stewart and Witts (1944) found that estimation of the amount of bilirubin, phosphatase, albumin and globulin from a single specimen of plasma usually provided as much information of diagnostic and prognostic value as could be obtained from more elaborate liver function tests.

Blood Examination : Cameron (1943) found leucopenia in many cases and an invariable neutropenia. Leucocytosis was never found at any stage and this was a point of difference from the Weil's disease. Seward (1943) found the total WBC count to vary from 4,000 to 7,000 per c.mm. and thought that early leucopenia was the rule. A relative lymphocytosis and high proportion of monocytes were sometimes found on differential count.

Urine Examination : Cameron (1942, 1943) noted increased urobilinogenuria in the pre-icteric stage and also when biliuria had ceased. The average duration of biliuria, which generally appeared on the day preceding the clinical recognition of jaundice, was nine days. Albuminuria was found in a few cases by Cameron (1943) and by Seward (1943) during the febrile stage of the disease but casts and RBCs were never found.

CLINICAL FEATURES

Since jaundice is not a feature of all cases it has been suggested (Cameron, 1943) that the disease be subdivided into :

(i) Infective hepatitis *cum ictero*—this comprising the great majority of cases;

(ii) Infective hepatitis *sine ictero*.

The symptomatology can be best divided into three phases, pre-icteric, icteric and post-icteric (Cameron, 1942).

Pre-icteric Phase: In the group of cases seen by Cameron (1943) in Palestine, majority started closely resembling sandfly fever with fever, malaise and headache though headache was less intense and the characteristic pain in the eyes was absent. But an invariable anorexia of very great intensity, nausea, a bad taste in the mouth variously described as ‘like rubber’ ‘sour’ or ‘bitter’, abdominal discomfort, discomfort and tightness rather than pain in the right upper abdomen and pyrexia varying as a rule between 99° and 103° F.

were the commonest symptoms. This phase with pyrexia continued for 3 to 6 days when jaundice appeared. Findlay *et al.* (1944) found that symptoms of post-yellow fever vaccine hepatitis were indistinguishable from those of infective hepatitis. The symptoms in the order of frequency were anorexia, nausea, epigastric pain, bad taste in the mouth, vomiting, lassitude, constipation and headache on the first day of disease. Hawley, McFarlan and Steigman (1944) noted that urticarial rashes and arthralgias were more frequent in hepatitis cases following plasma administration.

Hunt (1944) found that the prodromal period of pre-icterus symptoms ranged from five and a half days as an average to three, four or even seven weeks, and that many cases of ' pyrexia of uncertain origin ' were really cases of infective hepatitis which sometimes occurred without concomitant jaundice. Havens (1944) found that the symptoms persisted for one to eighteen days (average five days) before the appearance of jaundice. The early cases of this disease could be distinguished from malaria and sandfly fever by the presence of extreme anorexia. In the group of cases noted by Gordon (1943) in the Middle East Force, the pre-icteric phase lasted on an average 4·1 days in the apyrexial cases and 5·8 days in the pyrexial cases which presented headache and limb pains in addition to predominating gastro-intestinal symptoms and anorexia. Seward (1943) has noted the frequency of presenting symptoms in his series from Calcutta and compared it with that of Cameron as shown in Table VI.

TABLE VI

Symptoms observed in cases of Infective Hepatitis (percentage).

Symptoms	Seward's series	Cameron's series
Anorexia	94	86·5
Nausea and epigastric discomfort or pain	84	
Bad taste in mouth	62	
Headache	40	50
Malaise	50	72
Vomiting	Minor symptoms	46
Diarrhoea	18	7
Constipation	38	25
Pale stools	86	
Dark urine	Probably invariable	
Furred tongue	Usual	
Itching	Nil	5
Joint pains	A few	
Urticaria	2	
Liver enlargement and tenderness ...	83 (one or both)	57 (Enlargement) 64 (Tenderness)
Splenic enlargement	10	27

The frequency of pyrexia in Seward's series could not be determined as cases entered the hospital on the fifth day after the appearance of jaundice when the pyrexia had disappeared.

Icteric Phase : Seward (1943) noted that icterus appeared on the fourth day on an average and in another series on the sixth day. It varied in intensity from faint staining to an intense orange yellow and lasted usually some 21 days but sometimes persisted for two to three months. The average duration of stay in the hospital of the series noted by Leishman and Kelsall (1944) was 29 days though exceptional cases retained jaundice for as long as 14 weeks. Cameron (1943) found that with the development of jaundice, the initial symptoms rapidly subsided, pyrexia ceased as a rule and there was return of appetite in many cases. The duration of jaundice ranged from 5 to 72 days with an average of 21 days and its intensity was related to the severity of symptoms. Bradycardia which characterises all virus infections appeared with the onset of jaundice but during the pre-icteric pyrexial phase tachycardia was the rule. Taylor (1943) noted the duration of jaundice to be few weeks but in one case bile pigments were present in urine and skin for five and a half months. Seward (1943) noted that pale stools were observed by patients on the fifth/sixth day and dark urine on an average on the third day of the disease. Payne (1943) found pale stools in 40 per cent., clay coloured stools in 40 per cent. and normal stools in 20 per cent. of his cases. Biliuria continued in this phase. Jaundice with itching and severe cholaemic symptoms was noted by Cameron (1943) only in a few cases. Biliuria was found in all cases of post-yellow fever vaccine hepatitis noted by Findlay *et al.* (1944).

Enlarged liver was found in 58·5 per cent. cases by Havens (1944), in 55·5 per cent. cases by Findlay *et al.* (1944), and in 50 per cent. cases by Gordon (1943). Splenic enlargement figures were 10·5 per cent. by Havens (1944), 10 per cent. and 27 per cent., respectively by Seward and Cameron, and 48·6 per cent. by Findlay *et al.* (1944) in their series of cases following yellow-fever inoculation.

Post-Icteric Phase : In this phase there was rapid improvement in symptoms though full liver function did not return and a patient could not be regarded as cured until all residual evidence of hepatitis disappeared.

RELAPSE

Cameron (1943) noted relapse only in two patients in his series and no genuine second attacks were met with. Leishman and Kelsall (1944) noted recrudescence of jaundice occasionally in their series but more common was a flatulent dyspepsia persisting for some weeks. Benjamin and Hoyt (1945) found a delayed convalescence in hepatitis following yellow-fever inoculation.

COMPLICATIONS

As regards nervous and ocular signs which are common in virus diseases, Cameron (1943) reported mental disturbances in two patients

and temporary ocular difficulty with accommodation in three patients in his series of 250 cases of infective hepatitis.

Byrne and Taylor (1945) found neurological lesions in five cases of infective hepatitis admitted to a CCS in Burma, four patients coming from the same unit. Muscular weakness, diminished reflexes and in two cases sensory impairment of lower limbs were found. In one patient symptoms suggestive of pyramidal lesion were present three months after the onset and in another patient acute myelitis developed in pre-icteric stage, residual weakness being present even two months later. But Byrne and Taylor (1945) favour a co-incidental association of the two diseases rather than neurotropism of the hypothetical virus as a cause of these manifestations because of extreme rarity of nervous complications in infective hepatitis. Stokes, Owen and Holmes (1945) also reported neurological complications in infective hepatitis from Assam and Bengal in 1944. Coma, convulsion, delirium and incontinence occurred 48 hours before death. Striatal and pyramidal lesions with rigidity, clonus, exaggerated tendon reflexes and extensor plantar response were seen. Haemorrhagic complications and peripheral neuritis also occurred.

Stokes and Miller (1947) found acute and sub-acute hepatic necrosis complicating infective hepatitis in an unusually severe epidemic in South Burma. The acute type presented as coma of unexplained origin and of sudden onset preceded by vague malaise, anorexia and slight fever. The cases simulated cerebral malaria. Serum bilirubin was increased though clinical jaundice might have been slight. Progressive rise in the temperature occurred in some cases and the liver which had been palpable and tender previously was no longer palpable. The liver dullness decreased and disappeared at a remarkable rate. Pupils were dilated and fixed, incontinence of urine was common and spasticity appeared commonly in the lower limbs affecting especially the longer muscles. Tendon reflexes were increased and ankle clonus invariably appeared before the end. Plantar response was usually flexor but sometimes extensor. Involuntary movements of choreiform type and petechiae and purpura of the skin occurred occasionally. Death ensued within a period of 4-24 hours after the onset of coma. This is well illustrated by the case of a sepoy aged 30 years who was admitted complaining of fever and anorexia for two days and with negative history for syphilis or treatment by injection. There was a slight tinge of icterus in the conjunctiva and increased liver dullness was present though the liver was not palpable. Blood smears showed no malarial parasites and urine contained no bile salts, pigments or increased urobilinogen. The patient went sharply into coma the same evening. The pupils were dilated, right arm was slightly spastic, all tendon jerks were brisk and there was sustained left ankle clonus. The patient became incontinent 2½ hours later, both arms became spastic and slight spasticity appeared in the left leg. Lumbar puncture revealed no abnormality. Death ensued four hours after the onset of coma. Autopsy revealed a small liver reddish yellow and purple, with widespread hepatic necrosis and sub-capsular haemorrhage. Myocardial, sub-pericordial, sub-pleural, sub-arachnoid, jejunal and renal pelvic haemorrhages were also present.

The sub-acute type pursued a less rapid course and was characterised by the additional signs of ascites and gaseous distension and the jaundice was always deep. The following is an illustrative case of sub-acute hepatic necrosis complicating infective hepatitis. A lance naik aged 28 years developed an ordinary attack of infective hepatitis and was treated in the hospital from 9 November to 2 December 1945. He had been treated with penicillin for syphilis three months previously. The patient was re-admitted on 1 January 1946, complaining of dyspnoea, constipation and heaviness of the abdomen. He was deeply jaundiced (serum bilirubin 8 mg. per cent.) had gross ascites and gaseous distension of the abdomen and serum proteins were 6·6 g. per cent. He went into coma on 19 January when serum bilirubin was 14 mg. per cent., slight spasticity appeared in both upper limbs and ankle jerks were brisk. He came out of coma for a few hours on the next day but slipped back into it again in the evening, temperature rose steadily and a sustained left ankle clonus was present. On 21 January pupils were dilated, the patient became incontinent and expired on the following day. At autopsy the liver appeared small, greenish yellow in colour, studded with small yellow nodules and fibrous stroma was increased. Histological examination revealed a sub-acute hepatic necrosis. Patchy phlegmonous inflammation of the gut was seen which doubtless caused the gaseous distension due to mild sub-acute obstruction. Sub-pericardial, small sub-arachnoid and large pulmonary haemorrhages were also seen.

The fulminating cases presented mental changes as the commonest presenting symptoms ranging from minor changes in behaviour to excitement, confusion and coma. Walters (1945) cites the instance of a patient who on the second day of an undiagnosed low fever, suddenly attacked the ward staff with a chair, and died 24 hours later in a coma from the acute necrosis of the liver. He also noted the occurrence of malignant metaplasia of the regenerating liver parenchyma as a rare late sequel of infective hepatitis. A Tamil sepoy treated by him for the above disease when on active service in 1942, remained in fair health until 1945, when ascites developed. On re-examination in a hospital in South India he showed an enormously enlarged, coarsely nodular liver and a clinical picture typical of advanced primary hepatic carcinoma.

Ascites might develop early in the disease in rare cases in which probably the liver was already in a state of sub-clinical cirrhosis from dietary deficiency. Generalised oedema has been seen in patients whose liver cells, severely damaged by infective hepatitis were unable to maintain an adequate serum albumin concentration. Instances of anuria associated with deep jaundice from infective hepatitis have been seen and a British patient who remained anuric and comatose for three days made a complete recovery from this hepatorenal syndrome.

DIFFERENTIAL DIAGNOSIS

Early cases simulate malaria and sandfly fever. The disease can be distinguished from spirochoetosis ictero-haemorrhagica in which

leucocytosis is the rule and extensive signs of kidney damage with albuminuria and casts are present. Inoculation of guinea-pigs with blood in the early stage and urine in the late stages confirm the diagnosis. Agglutination reactions against the leptospira develop as early as the third day and are always present by the tenth day. Seward (1943) made half a dozen such tests in his series and results were uniformly negative. Yellow fever which does not occur in India and has haemorrhagic features is also to be excluded. Obstructive jaundice, with its many causes can be excluded by clinical observations. Cameron (1943) has observed that the following five points are to be recognised as of major importance in the early diagnosis of infective hepatitis: anorexia, abdominal discomfort with or without hepatic enlargement and tenderness, absence of leucocytosis, increased urobilinogen in the urine and histamine wheal test for latent jaundice.

PROGNOSIS

No deaths occurred in the series observed by Cameron (1943) and most patients made a complete recovery in 35 days though a few cases continued beyond 10 weeks. It may also be recalled that in the series of 34 cases in South Burma, where a local virulent strain of virus of infective hepatitis was at work, liver parenchyma was rapidly destroyed and seven cases died within ten days of appearance of the symptom.

Mortality rate, as stated above, is higher amongst the Indian than British troops. Amongst Indian the mortality is higher in females than in males.

Small percentage of cases of acute hepatitis progress to chronic hepatitis and finally lead to post-necrotic scarring and nodular hyperplasia or healed yellow atrophy. None of the cases in Wahi's (1951) series showed changes characteristic of diffuse hepatic fibrosis or cholengioletic cirrhosis or hypertrophic biliary cirrhosis.

TREATMENT

No specific form of therapy is known. Questionably beneficial results were obtained by Oram (1945) with convalescent serum treatment.

Cameron (1943) emphasised that the essence of treatment lies in the understanding that it is a liver disease and not a skin colouration. A minimum of one month's stay in the hospital and absolute rest in bed for at least a fortnight were found necessary by him even in the mild cases where jaundice disappeared earlier. A diet containing carbohydrates, liberal protein and normal fat was reached as early as possible. Fat and cholesterol were restricted in the presence of clay coloured stools and sometimes bile salts were given so that fat could be introduced with the diet. An adequate intake of vitamin K was ensured in view of the haemorrhagic tendency seen in this disease. Aperients like calomel and magnesium sulphate were given as

required so that biliary drainage was also facilitated. On the first suspicion of haemorrhage, oral or parenteral preparations of vitamin K were given and if this was unsuccessful immediate transfusion with fresh blood which contains prothrombin was undertaken.

Seward (1943) advocated a high protein, high carbohydrate and a low fat diet (P 100, F 20, C 450 g.). He maintained that skimmed milk and cheese should be included in the diet in view of their casein content as choline, essential for fat metabolism in the liver, is derived from the amino acid methionine. Darmady (1945) could not obtain beneficial results in infective hepatitis with a high protein diet. Wilson, Pollock and Harris (1945) and Higgins, O'Brien, Peters, Stewart and Witts (1945) could not obtain statistically significant result with administration of 5 g. of methionine orally in infective hepatitis cases.

On the other hand Peters, King, Thompson, Williams and Nicol (1944) had reported good results with methionine and cystine in post-arsphenamine jaundice cases. Beattie and Marshall (1944) observed that post-arsenical jaundice could be prevented or minimised by methionine and it influenced beneficially the clinical course of infective hepatitis and post-arsphenamine jaundice. The Jaundice Research Team organised by the Jaundice Committee of the MRC reported that the results of therapeutic trials with diet and dietary principles carried on by them on strict statistical lines in the United Kingdom were, unfortunately, almost completely negative. There was no difference in response whether the protein or the fat content of the diet was high or low nor the value of lipotropic substances such as methionine, choline or cystine was proved though there was a suggestion that cystine had some therapeutic effect.

As regards vitamin therapy, Seward (1943) maintained that in addition to vitamin K, vitamins A and D should be given in view of fat restriction in diet and a component of vitamin B complex in the form of yeast was necessary for proper liver function.

Stokes and Miller (1947) noted that in their series of cases in South Burma, the mortality rate was rising though the incidence of the disease was falling. All cases were treated with the respect they deserved as a liver disease and the following four criteria namely complete return of appetite, and the absence of hepatic tenderness, clinical jaundice and bile pigments in urine, were observed before a patient was discharged. Intravenous plasma was administered when oral protein intake failed and glucose saline was given by a Ryle's tube when the patient could not take any fluid by mouth. Since post-mortem examination revealed cerebral oedema in many cases, nursing in the upright position was advocated. This therapy was followed even when the outlook was hopeless and four cases in this series recovered though they were in coma for many days.

Cameron (1943) has observed that alcohol should be prohibited for at least six months after recovery as alcohol lowered the resistance of liver and hepatitis might be incompletely healed.

It will be seen that the treatment briefly consists of rest in bed and diet with enough protein and calories. Rest in bed is essential till the urine is free from bile for at least a week and no heavy work should be permitted for another three months.

From the epidemiological point of view patients should be isolated as far as possible specially in the early stages as they are infective. Diagnosis and removal in pre-icteric phase is important. They should not be nursed in the wards, with other acutely ill patients as these form a ready soil for infection. Contacts should be under surveillance for 35 days after removal of the source of infection.

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CHAPTER XIII

Leishmaniasis

VISCERAL LEISHMANIASIS

INTRODUCTION

Kala-azar or visceral leishmaniasis is highly prevalent in the eastern half of India, and particularly in Bengal and Assam[1], where the Eastern Army and the Fourteenth Army operated for a considerable period during World War II. Soldiers were also recruited to the armed forces from known endemic centres of kala-azar. The disease was frequently seen in Gurkha recruits, most of whom came from Nepal. It was, therefore, not surprising that cases of kala-azar were met with in the military hospitals, mostly in Indian troops. However, the disease never formed a major military problem in the eastern theatre.

[1] Epidemics of the so-called 'Burdwan fever' were reported from 1854-57 in South Bengal. Its origin, however, remained almost obscure until 1882 when Clark of the Sanitary Commission of India described 100 cases of 'malarial cachexia' in Garo Hills, Assam, where it was called 'Kala-azar' (black fever) for decades. Napier reported a severe epidemic of this fever in Nowgong between 1890-1900. The prevalence of the disease in Assam and Bengal is now well known.

Although kala-azar has not been a major medical problem even of the peace-time Army in India, it is interesting to mention that many important observations pertaining to the disease were made in India, and chiefly by army personnel. Leishman in May 1943 observed what he considered a degenerated form of a trypanosome in the spleen pulp of a soldier who died of dumdum fever. Donovan in Madras in July of the same year reported the finding of similar parasites in the specimens from splenic punctures of cases of dumdum fever taken during life. The parasite was ultimately named *Leishmania donovani*. Subsequent contributions to kala-azar research by members of the armed forces were by Rogers who cultivated the organism in artificial media ; McCombia Young who worked out the epidemiology and Christophers, who detected the pathology of the disease in men ; Knowles and his colleagues who showed the association between the sandfly, *Phlebotomus argentipes* and the disease ; Chopra who discovered a simple test for the diagnosis of kala-azar; Smith and his associates who produced experimental proof of the transmission of infection to hamsters and mice by the bites of infected sandflies ; and Shortt and Anderson who in collaboration with Swaminath corroborated Smith's findings and finally transmitted the disease to human volunteers.

Shortt (1945) conveniently divides kala-azar research in India into three periods. Firstly, when serious epidemics occurred in Bengal ; secondly, discovery of the causative organism and elucidation of the pathology of the disease ; thirdly, the most important recent period when effective methods of treatment with urea-stibamine discovered by Brahmachari in 1922 and successful transmission experiments in animals as well as human volunteers were carried out.

In addition to the eastern half of India, visceral leishmaniasis is also prevalent in China, north of the River Yangtse, and in countries of the Mediterranean Littoral. Other small foci of infection exist notably in East Africa and Sudan (*see* Appendix A).

In India, Assam used to be the hot-bed for this disease in the latter part of last century. The disease existed or seemed to have spread westwards, and now with improved methods of diagnosis, it is found all over Bengal, North Bihar, Orissa, Eastern United Provinces and Madras Presidency. Sen Gupta (1944) analysed the incidence of the disease in Bengal during the decade 1931-40 from the dispensary and hospital statistics of the Government of Bengal. A total of 1,146, 686 cases of kala-azar were observed during the period or 210 cases per annum for every 100,000 of population. A very unequal distribution was seen in the different districts, being high in Murshidabad, Malda, Rajshahi and Jessore, and low in Bankura and Birbhum. A report on kala-azar in Bihar by the Inspector General of Civil Hospitals revealed that 92,000 cases were treated in 1938, of these 83,961 cases occurred in North Bihar alone.

INCIDENCE

In the Army in India, the admission rate for kala-azar among Indian troops was on the average about 0·3 per 1,000 during the period 1939-46.

TABLE I

Incidence of kala-azar among VCOs and IORs in the India Command (1939-46).

Year	ADMISSIONS		DEATHS		INVALIDS		AVERAGE CONSTANTLY SICK	
	Actuals	Rate per 1,000	Actuals	Rate per 1,000	Actuals	Rate per 1,000	Actuals	Rate per 1,000
1939	57	0·5	3	0·03	3	0·03	9·82	0·08
1940	46	0·3	4	0·02	7	0·04	10·98	0·06
1941	102	0·3	7	0·02	8	0·02	13·81	0·04
1942	90	0·2	6	0·01	11	0·02	11·80	0·02
1943	124	0·2	11	0·01	33	0·04	21·27	0·03
1944	257	0·3	15	0·02	18	0·02	44·94	0·05
1945	304	0·3	8	0·01	32	0·03	51·07	0·06
1946	161	0·2	4	0·01	23	0·04	24·60	0·04

EPIDEMIOLOGY

Causative Agent: So far two species of leishmania are known to be concerned in the causation of visceral leishmaniasis, *L. donovani* in India and *L. infantum* in the Mediterranean Littoral. But morphologically and serologically they appear to be the same parasite. In the Mediterranean Littoral the reservoir of infection has been found to be the dog. Similarly, Chung (1940) advanced evidence that dogs were reservoirs of infection of kala-azar in North China as well and that *L. donovani* and *L. canis* were identical parasites. Chung and Lu (1941) produced further experimental evidence to prove that the parasites of human and canine kala-azar were identical or were very closely related to one another. They carried out cross complement-fixation reactions with sera from cases of human and canine kala-azar which were identical or were very closely related to one another. They carried out cross complement-fixation reactions with sera from cases of human and canine kala-azar and with sera of rabbits injected intravenously with parasites from the spleens of hamsters. The antigens were prepared from the spleens and livers of moles and hamsters experimentally infected with *L. donovani* and *L. canis*. In India, no animals other than man have been found to harbour the infection of the Indian form of the disease. About 5 per cent. of the sufferers of the Indian kala-azar, however, develop a skin infection called, post-kala-azar dermal leishmaniasis as a sequel to treatment or natural recovery and it is these

cases that serve as a reservoir of infection between inter-epidemic periods. The East African form of kala-azar is very resistant to treatment with the known antimonial preparations which cure Indian and Mediterranean forms. It is possible that the infecting leishmania of African kala-azar is different from the Indian or Mediterranean types (Smith, 1949).

SPREAD OF KALA-AZAR

Kala-azar is recognised to be a place or house disease. This is due probably to the bionomics of the insect vector sandfly, of which there is still very much to learn. The chief vectors are *P. argentipes* in India and *P. perniciosus* in the Mediterranean Littoral and *P. chinensis* in North China. Kala-azar takes several years to spread to new localities and periodically assumes epidemic proportions. During epidemic periods a typhoid or malaria like onset is frequently seen, but during inter-epidemic periods the onset may be slow and insidious with hardly any symptoms to suggest the true nature of the disease. It is generally agreed that in an infected person, the causal agent may remain quiescent in the skin for two years or longer and then give rise to a generalised visceral infection when the resistance has been lowered by such diseases as malaria, typhoid or dysentery. From these and other observations it would appear that the great majority of cases occurring in Indian troops, serving in various theatres of the war, were from those that had been recruited from endemic areas. Cases also occurred amongst British troops while they were stationed in Bengal and Assam. Indian cases probably had been infected in their homes, and under the stress of war conditions or as a result of suffering from diseases which lowered their resistance to leishmania infection, developed the disease.

RESEARCHES IN EPIDEMIOLOGY IN INDIA

It was found that experimental infection of kala-azar in animals could be produced by a variety of methods such as intraperitoneal inoculation of nasopharyngeal secretions from kala-azar patients, contact with infected animals under insanitary conditions, ingestion of faeces of infected animals, contamination of the conjunctiva with infected material, and feeding on or intraperitoneal inoculation of sandflies which had ingested the parasites. All these and various other possibilities had to be considered before the natural method of transmission which is by the bite of sandfly, could be arrived at.

The first successful transmission of *L. donovani* by the bite of the sandfly, *Phlebotomus argentipes*, was obtained in a hamster in 1931 by Shortt, Smith, Swaminath and Krishnan (1932). In 1933 Napier, Smith and Krishnan could infect two out of twenty-eight animals. Similarly in 1935, Smith, Lal, Mukherjee and Halder succeeded in experimentally transmitting the disease to only one out of sixteen animals. These results, although confirming the view that *P. argentipes* could transmit *L. donovani* infection by its bite, did not prove that sandfly was a natural vector of

the disease in view of the very small number of the highly susceptible hamsters that could be infected by transmission experiments.

During World War II, certain notable advances in the knowledge of Indian kala-azar were made in India. Smith, Haldar and Ahmed (1940) found it possible to keep sandflies alive for a longer period by allowing them to nourish on raisins, instead of giving blood-meals, after the first infective feed on a kala-azar patient. This had the added advantage from the point of view of transmission experiments as larger flies with heavier infection could be obtained. The previous assumption that blood feeds were necessary for the satisfactory development of leishmania in the flies was found to be erroneous.

The phenomenon of blocking in sandflies, similar to the blocking of the oesophagus of fleas with plague bacilli, was noted in 1926 by Shortt, Barraud and Craighead (1927). Smith *et al.* (1940) used their new feeding technique in observing the phenomenon of blocking. The sandflies, after their first infective feed on a kala-azar patient, were kept on a raisin diet till the tenth day, when they were allowed a second blood-meal on an experimental animal. It was found that some of the flies could not imbibe blood though they made strenuous efforts to do so. It could be assumed that, during such vain attempts, the flagellates were dislodged and discharged by the blocked flies into the proboscis wound of the experimental animal. In a series of 225 known positive flies dissected, 58 had been diagnosed as blocked, and of these 49 showed heavy infection with flagellates. Encouraged by the facts noted above, which afforded better opportunities for transmission experiments, Smith *et al.* (1940) exposed five hamsters and ten mice to the bites of infected sandflies.

All the five hamsters and two of the mice were proved to be infected with kala-azar. The longest incubation period was seven months in the case of a mouse. It was observed that blocked flies were not essential for transmission since the two mice were not fed on by blocked flies. On the other hand, one hamster on which blocked flies alone were allowed to feed, acquired a particularly heavy infection. Smith *et al.* (1940) maintain that the success of these experiments was due to inoculation of heavy doses of flagellates by blocked or partially blocked flies whereas the previous experiments did not succeed as the flies were kept on blood-meals which did not allow them to acquire such heavy infections and moreover human blood-serum is known to have a definite lytic action on the flagellates. However, as Smith *et al.* (1940) could not exclude the fact that increased virulence of the particular strain of leishmania used could have accounted for their success, they (Smith *et al.*, 1940) carried out a second series of experiments. A batch of sandflies, after their first infective feed on a kala-azar patient, was divided into two lots ; one lot was maintained on raisin diet whereas the other was given repeated blood-meals. Each lot was allowed to feed separately on two batches of hamsters, five animals being included in each batch. Each animal was approximately given ten infective feeds. All the five animals inoculated by raisin-fed flies became infected whereas in the other

series four animals did not acquire any infection and the fifth which escaped could not be studied.

The notable event of the series of epidemiological investigations, which commenced in India twenty-five years ago, was the successful transmission of the disease by Swaminath, Shortt, and Anderson (1942) to each one of the five healthy human volunteers who did not come from endemic areas. The volunteers were fed on by a number of sandflies, which after their first infective feed on a kala-azar case, had been maintained on a raisin diet.

PATHOLOGY

Leishman-Donovan (LD) bodies are found crowded together in the endothelial cells of blood-vessels and lymphatics, specially those of spleen, liver, bone marrow and skin. De of Medical College, Calcutta, had conclusively proved the presence of LD bodies in every organ of the body, after a post-mortem examination. Menon (1939) regards kala-azar as a reticulo-endotheliosis due to parasitic invasion of the cytoplasmic reticular syncitium. There is a gradual formation of free parasitised histiocytes, and in the later stages, infection spreads to the lymphatic reticulum of the spleen. Reticulo-endothelial blockage is the probable cause of the anaemia and the tendency to inflammatory complications. Chatterjee (1946) made a study of the femoral bone-changes in fatal cases of kala-azar. In an acute case there was almost complete absorption and replacement of fat cells. The general structure showed a large number of clasmatocytes (30 per cent. containing leishmania) and cells of myeloblastic series. In the sub-acute cases, reddish marrow was tougher than normal. The cells diminished in certain areas and presented a ground-glass appearance due to precipitation of fine fibrils in the fat vacuoles. Some increase in argyrophil reticular fibres was also noted. All clasmatocytes were found to contain leishmania. In the chronic cases there was further reduction of cells, specially of the myeloid series. The clasmatocytes were packed with parasites and were most conspicuous among the reticulo-endothelial cells. The fibrils were more pronounced and there was further proliferation of the argyrophil reticular fibres. A progressive degeneration of the marrow and cellular changes explain leucopenia, neutropenia and increasing anaemia.

SYMPTOMS

Bose (1944) observed that kala-azar produced a high mortality in untreated cases and caused much confusion to the unwary in the diagnosis as it was frequently associated in the tropics with other infections. It was a good practice in the diagnosis of early cases to find out the patient's permanent home and his recent movements in and outside India. The incubation period was variable and uncertain. The insidious onset was frequently ushered in by fever of varying duration and range of temperature ; not infrequently the temperature chart

resembled that of enteric fevers, or of quotidian type of malaria ; bouts of fever lasting ten to twelve days were usually followed by an irregular apyrexial interval ; sometimes the fever remained continuous. The spleen became palpable and no specific cause could be found. This was the period when associated signs and symptoms roused one's suspicion, e.g., good appetite, clean tongue, peculiar absence of toxaemia and leucopenia. In the later stage, when infection was well established, signs such as muddy complexion, coarse and dry hair, pigmentation of the skin and mucosa, haemorrhages especially epistaxis, anaemia, diarrhoea, debility with splenomegaly and not infrequently, hepatomegaly could be observed. Later still, appeared ascites, cachexia and cancrum oris. The disease was commonly associated with malaria, dysentery, hookworm and tuberculosis, which sometimes proved to be a terminal and fatal factor.

Hardy and Passmore (1945) made observations on 50 cases of kala-azar occurring in sepoys evacuated from Assam and Arakan field of operations to an IBGH. They observed that although the usual features present were fever, splenic enlargement, leucopenia and changes in serum protein giving rise to positive aldehyde test, the only two features that were constantly present in all cases were fever and the therapeutic response to urea-stibamine. In 90 per cent. of cases the diagnosis was conclusively made by finding the parasites in sternal puncture smears. Sternal puncture was found to be a safe and reliable procedure, which could be repeated if necessary, but the smears required a laborious search as sometimes only a few extracellular forms could be found. The fever was characterised by its irregularity. It did not cause much inconvenience to the patient and rigors and intense shivering were uncommon. A double rise was not necessarily present. Frequently, a striking temperature swing from 105° F. to below normal occurred within a short period, and occasionally a sustained typhoid like temperature was noted. Remissions occurred frequently but a complete apyrexial period of more than three weeks was uncommon. A progressive enlargement of the spleen usually occurred during the course of the disease, but in some of the early cases and in three fatal cases, the spleen did not show any clinical evidence of enlargement. Leucopenia with depression of the granular cells was marked. In 80 per cent. of the cases WBC count was below 4,000 and in 60 per cent. cases it was below 3,000. One case, diagnosed as agranulocytosis, was received with leucocyte count of 1,100 of which only 5 per cent. were polymorphs. A positive aldehyde test in the absence of any gross enlargement of spleen was found to be a reliable method for routine diagnosis. In differential diagnosis, the enteric group of fevers, chronic malaria (splenomegaly), tuberculosis and other chronic infections had to be chiefly considered. Irregularity of fever, lack of correspondence between the fever and the degree of toxaemia, progressive leucopenia, a strongly positive aldehyde test and lack of response to anti-malarial therapy, were some of the points which differentiated kala-azar. But a diagnosis of kala-azar could only be made with certainty by finding the specific organism. In the series of cases noted above, complications were few. One patient had a severe septic stomatitis and another repeated attacks of epistaxis.

Except the two fatal cases which could not be diagnosed early enough, the rest were effectively treated with urea-stibamine with a standard total dose of 2·5 g.

Kiloh (1944) reported 10 cases of kala-azar among BORs. He observed that kala-azar did not lend itself to early diagnosis in British troops, and the disease inevitably progressed to a fatal outcome in the absence of treatment. Considerable number of British troops were stationed in endemic areas and it was only natural to expect that the incidence of the disease in British troops should rise. The BORs investigated were exposed to the 1942 monsoon in endemic areas of India. Three patients were admitted for other conditions, one for BT malaria and the other two for dysentery, one amoebic and one bacillary. The remaining seven gave symptoms of vague ill-health culminating in fever. On admission the patients were febrile but general condition was good. They continued to be bright and cheerful without any evidence of toxaemia during their stay in hospital. Spleen was palpable in all cases except one in whom progressive leucopenia aroused suspicion. Temperature chart was variable. Leucocyte count was valuable in aiding diagnosis. A moderate, slowly progressive leucopenia, affecting the granular series alone, was observed. A rise in leucocyte count following treatment indicated successful therapy. Aldehyde test was negative in all and Chopra's antimony test was positive in only one case. Sternal puncture was used as a routine method for diagnosis and yielded positive results in eight cases. In the remaining two, spleen puncture had to be performed to confirm the diagnosis. Urea-stibamine was successfully employed in treatment of all the cases, a total dose of approximately 3 g. being administered.

An interesting case was reported from the IMH Dunkirk, Poona, of a Bengali who was febrile with enlargement of liver and spleen and a WBC count of 5,000 with 34 per cent. polymorphs. All investigations including sternal puncture were negative. Eventually a strongly positive result was obtained by the WKK complement-fixation test. The patient responded quickly to a course of urea-stibamine.

DIAGNOSIS

Clinical: Special clinical features, viz., muddy complexion, soft enlargement of spleen, sometimes hepatomegaly, fever (with double daily rise in some cases only), cachexia, pigmentation, septic stomatitis, cancrum oris, haemorrhages and gastric disturbances, have already been mentioned above. It is often asserted that a physician with sufficient experience in an endemic area can make almost always a correct diagnosis from the characteristic appearance of the patient. It must, however, be stated that diagnosis on clinical grounds alone cannot be relied upon.

Haematological Examination: Haematological examination similarly is helpful but not entirely diagnostic. Bose (1944) observed that leucopenia, relative diminution of granulocytes and increase in monocyte

occur in kala-azar cases and if malaria could be excluded increase in monocytes are highly significant. Parasites are generally present in untreated cases in the peripheral blood. It is possible to establish diagnosis in 60 to 70 per cent. of cases when stained leucocytic edge of 4-6 slides is examined carefully.

Complement-Fixation Test : Reference has been made above to complement-fixation, aldehyde and antimony tests.

A complement-fixation test was developed involving the use of an antigen prepared from acid-fast bacilli called the WKK antigen. This work which was initiated by Bier was modified by Greval, Lowe and Bose (1939), Greval, Sen Gupta and Napier (1939), and Sen Gupta (1944) at the School of Tropical Medicine, Calcutta to obtain a high percentage of positive results in kala-azar. Lowe and Greval (1939) reported positive results in all the 17 cases examined of Indian kala-azar and in one of three cases of dermal leishmaniasis. Greval *et al.* (1939) found that all the 132 diagnosed cases of kala-azar were positive by complement fixation test with WKK antigen. In a series of 434 cases, Sen Gupta (1943) reported 97 per cent. positive results in diagnosed cases of kala-azar (172 out of 177 cases) and found that the test was negative in all other diseases except chronic pulmonary tuberculosis, severe leprosy and post-kala-azar dermal leishmaniasis. Sen Gupta (1944) employed easily cultivable acid-fast organisms such as *Mycobacterium phlei* and *Kedrowskg's bacillus* for the preparation of WKK antigen and found that a positive reaction was obtained within three weeks in some cases. In a series of 864 cases, he obtained positive results in 93 per cent. of diagnosed kala-azar (241 out of 260) cases.

Ghosh (H), Ghosh (N.N.) and Ray (1945) reported very successful results in the diagnosis of kala-azar by complement-fixation test with a specific antigen prepared from flagellate cultures of *L. donovani.* The test was found to be highly specific and positive in early cases of kala-azar when the usual serum tests were negative. In a series of 1,038 cases, Ghosh *et al.* (1949) obtained positive results in 99 per cent. of diagnosed cases of kala-azar (192 out of 194 cases). In two cases of kala-azar in the above series, positive results were obtained as early as the twelfth and fourteenth day, respectively since the onset of fever.

Rose (1945) reported the occurrence of cold-agglutinins in high titre in two cases of visceral leishmaniasis. In one case, which was followed up, agglutinins returned to within limits after recovery.

In 1945, Serological Laboratory, Calcutta, was equipped to carry out complement-fixation tests for early and doubtful cases of kala-azar amongst the armed forces. Antigen was provided by the School of Tropical Medicine, Calcutta, in the beginning but later on the laboratory started manufacturing its own antigen. In 1946, when the number of specimens received by this laboratory became few and controls were not always available, it was decided to discontinue this test in the military laboratories. Through the courtesy of the Director of Tropical School, Calcutta, all specimens were sent to this institute which carried out a large number of examinations.

Aldehyde Spackman's (Napier) Test and Antimony (Chopra's) Test : Antimony test has an advantage over aldehyde test as the positive results in the former are obtained earlier but care should be taken in the interpretation of result from cases with large spleen as false positive results may sometimes ensue. On the other hand in a well-established case with a large spleen, the aldehyde test can be relied upon better than the antimony test. A general summary of the two serum tests is given below :—

	Antimony (Chopra's) test	Aldehyde Spackman's (Napier) test
Doubtful positive	1 month	2 to 3 months after onset
Strongly positive ...	2 months after onset	5 months after onset
Splenomegaly due to other causes	Sometimes positive	Negative
In early kala-azar with moderate spleen	Positive valuable	Usually negative
In early kala-azar with marked splenomegaly	Positive of no certain value	Usually negative
During treatment	Result variable	Variable. Time of gelation increases
After full treatment ...	Negative	Negative or the time of gelation increased usually more than 1/2 hour

Kiloh (1944) observed that the formolgel test becomes positive in schistosomiasis and trypanosomiasis as well but this was not likely to confuse the issue in India. Laha (1940) observed that aldehyde test was limited in value as it became positive only after four months and gave positive results in other diseases such as advanced tuberculosis, leprosy, schistosomiasis, trypanosomiasis and even malaria.

BIOPSY

Shortt (1945) considered spleen or liver puncture and in very young children tibial puncture with microscopical examination of stained smears as the diagnostic method of choice. Sternal puncture proved to be less reliable. Reddy and Subramaniam (1939) observed that negative sternal puncture does not exclude kala-azar. In two cases diagnosed by splenic puncture, sternal puncture failed to reveal leishmania. Napier (1939) observed that though sternal puncture was fairly accurate, it was not so reliable as splenic puncture. In the Army in India, LD bodies were found on 21 occasions in 81 splenic punctures and on 178 occasions in 923 sternal punctures performed during 1945. In 1946, LD bodies were found on 47 occasions from 390 bone-marrow smears from suspected kala-azar cases which were examined.

In Sudanese suffering from kala-azar, gland puncture appeared to be an effective diagnostic procedure and leishmaniae were found by Kirk and Sati (1940a) in 30 cases from smears of gland juice thus obtained. Similar results were reported by Davies and Wingfield (1941) in a limited series of cases.

It will be obvious that the diagnosis of kala-azar by clinical signs and symptoms is not always reliable. In the early stages (which may be enteric like, malaria like, insidious type or even asymptomatic) the demonstration of leishmania is usually necessary. In the later stages serum tests are of value as confirmatory evidence in patients with suggestive signs and symptoms. Pasricha (1941) recommends the following methods to be adopted in the order of preference for demonstration of leishmania, viz., sternal puncture, spleen puncture, liver puncture, examination of peripheral blood and blood culture and the various serum tests which depend on the increase of globulin fraction.

The flagellates can be cultured from the blood with proper technique in almost 100 per cent. of positive cases. It is a slow process and the diagnosis is often delayed for two to three weeks. Biopsy material can also be cultured directly on N.N.N. medium.

THERAPEUTIC TEST

It is not justifiable to start antimony injections to establish diagnosis in cases suspected to be suffering from kala-azar. Diagnosis becomes very difficult once antimonials are given. There is urgency in these cases and treatment should be started immediately on the establishment of the diagnosis but it must be emphasised that treatment with antimony should not be given unless definite diagnosis has been made.

COMPLICATIONS AND SEQUELAE

Napier, Kirwan and Sen (1941) noted that post-kala-azar dermal leishmaniasis develops in 5 per cent. of kala-azar patients in India. They mentioned an interesting case in which leishmanial keratitis of a nodular type occurred in one eye completely obstructing the vision. A course of therapy with iodides and organic antimonials caused resolution of the skin and ocular lesions and restoration of vision. Brahmachari and Basu (1942) reported ulcerating type of dermal leishmaniasis with pseudo-arthritis and ichthyotic condition of the skin. Brahmachari (1943) described the various stages in post-kala-azar dermal leishmaniasis as firstly erythema, then depigmentation, followed by small reddish patches or coalesced red papules and red nodules. Some cases respond to antimonials, others are resistant and some occupy an intermediate position.

Acute agranulocytosis as a complication of kala-azar, though common in North China, is not so in India. Das Gupta and Sen Gupta (1943) noted that, during a period of ten years at the School of Tropical

Medicine, Calcutta, where several thousand cases were treated, only one case of acute agranulocytosis was seen who had only 750 white cells per c.mm.

Sen Gupta and Chakravarty (1945) reported six cases of cancrum oris complicating kala-azar.

TREATMENT

The specific remedy, urea-stibamine, (pentavalent antimonial preparation), introduced by Sri U. N. Brahmachari in 1922, was the most widely used drug in India during the war in spite of the appearance of other successful organic antimonials. Shortt (1945) observed that it was difficult to conceive of any marked improvement over the available antimony preparations which cured kala-azar sometimes in a matter of days. Bose (1944) advocated an initial dose of urea-stibamine 0·05 g. for a man weighing 9 stones, to be followed by daily injections of 0·1g., 0·15 g. and 0·2 g. until the temperature came down, and then, on alternate days 0·2 g., until a total dose of 3 g. is reached. It was essential at the same time to give specific treatment for any associated illness. Good results were obtained by administration of vitamins, intravenous calcium and iron therapy simultaneously. Sen Gupta and Chakravarty (1945) obtained good results with penicillin therapy combined with pentavalent antimony in his cases of cancrum oris complicating kala-azar. The patients should be under observation for at least a year, during which period, a record of the haemogram and the weight should be kept, and a modified course of specific treatment repeated, if splenomegaly and abnormal blood-picture continue to persist. Pasricha (1941) recommended that urea-stibamine should be given intravenously on alternate days or three times a week, but not daily. The course of treatment is from 12 to 15 injections, initial dose 0·05 g., second dose 0·1 g., third dose 0·15 g., and fourth and subsequent doses 0·2 g., each.

Rogers (1939) observed that tartar emetic introduced by Christina and Caronina in Sicily and by himself in India gave good results. But it was later replaced by urea-stibamine of Brahmachari which was less toxic than tartar emetic but appeared to be of uncertain composition and varied in its antimony content. In Germany, neostibosan for intravenous therapy and solustibosan for intramuscular therapy were introduced ; with which a cure rate of 90 per cent. could be expected. Napier (1939) observed that neostibosan treatment of all cases in some Bengal villages was followed by the disappearance of the disease. Similar results were obtained with urea-stibamine by the Assam Government in treating 300,000 cases between 1923-25. Pasricha (1941) recommended a freshly prepared 5 per cent. solution of neostibosan, initial dose 0·2 g. and subsequent doses 0·3 g. to be given daily till a total dose of 3·2 g. (optimal course of eight injections) is administered. Symptoms of anaphylactic character sometimes appear after pentavalent antimony injections. Urea-stibamine occasionally gives rise to toxic vomiting.

In Sudanese kala-azar, organic antimonials appear to be less effective. Higher initial doses and longer period of treatment have

been found necessary but with less dramatic results. In cases of Mediterranean kala-azar, difficult to treat with neostibosan, a concentrated aqueous or oily solution of neostibosan has been successfully employed by Kikuth and Schmidt (1944) in treating children with safety. Fernandez (1945) observed that the method of choice in treating infantile kala-azar was with oily suspension of hexonate of antimony (sodium antimony gluconate). Burke and Chakravarty (1944) found sodium antimony gluconate (stibatin) to be a good anti-kala-azar remedy. It could be given intramuscularly and was preferred for its specific action, low toxicity and the ease of administration. Similar views were expressed by Patel (1944) and Sen Gupta and Chakravarty (1945) regarding sodium antimony gluconate. Chakravarty (1945) and Kirk and Sati (1947) have reported encouraging results in Sudanese cases. Successful results were reported by Brahmachari (1941) with a derivative of p-aminophenyl stibinic acid (antimony content 41 per cent.) named neostebene. It was given bi-weekly in doses of 0·1 g., total doses 1 g. to 4 g.

Further advance in the treatment of kala-azar is exemplified by the use of the aromatic diamidines synthesised first by Ewins. The experience gained in India with these drugs has shown that their use in the treatment of leishmaniasis is to be restricted to certain types of cases only, as disconcerting immediate and remote effects are met with, debarring its use in routine treatment. However, good results have been obtained with the aromatic diamidines at the School of Tropical Medicine, Calcutta. Napier and Sen (1940) obtained good results with diamidine in the treatment of eight cases of kala-azar and one of post-kala-azar dermal leishmaniasis. Initial dose used was 0·001 g. per kilo, subsequent dose 0·002 g. per kilo and the maximum dose was 0·001 g. per lb. body-weight. Immediate symptoms such as flushing, burning sensation over chest and abdomen and slight dyspnoea were attributed to the injections but relief occurred with adrenaline. Napier, Sen Gupta and Sen (1942) obtained successful results with diamidino-stilbene in 100 cases of Indian kala-azar; 98 were cured, of which two relapsed. Antimony resistant cases responded equally favourably. The alarming symptoms of fall of blood-pressure could be controlled by giving adrenaline previously. The drug had no action on cutaneous leishmaniasis. Napier and Sen Gupta (1942) reported a remote neurological complication after treatment with 4 : 4-diamidino-diphenyl-ethylene. There was anaesthesia to light touch over trigeminal area but sensations of pain, temperature and pressure were preserved. This was attributed to a lesion in the pons involving the principal sensory nucleus of the trigeminal nerve. A marked fall of blood-pressure occurred after the first few injections but it returned to normal in 5 to 10 minutes. Fulton and Yorke (1942) observed that stilbamidine (diamidino-stilbene) should be used as a freshly prepared solution as it undergoes deterioration on exposure to sunlight. Napier and Sen Gupta (1943) concluded that diamidino-diphenoxy-pentane has also a marked anti-kala-azar activity. Though it appeared more benign in action, it was less effective also as a curative agent. Similarly 4 : 4-diamidino-diphenyl-ether was found inferior to stilbamidine and pentavalent antimonials (Sen Gupa, 1945). Sen Gupta (1943) concluded that, of the

various aromatic diamidines used, diamidino-stilbene appeared to be the most powerful therapeutic agent. Its disadvantages were that it produced immediate alarming reactions (though avoidable by the use of adrenaline) in the majority of cases and troublesome neuropathic sequelae followed in some cases though these were also entirely curable. In India pentavalent antimony compounds were preferred because of the ease of administration and rarity of unpleasant reactions. GHQ Medical Directorate, issued an administrative instruction in 1946, to the effect that stilbamidine should not be prescribed without reference to the consultant physician or command adviser in medicine owing to the risk of subsequent nerve palsy.

In complicated cases of kala-azar where antimonials were contra-indicated, aromatic diamidines were found useful. Sen Gupta (1944) treated a case of kala-azar, complicated with tuberculosis, with diamidino-stilbene and cured the patient of leishmania infection.

Kirk and Sati (1940*b*) reported good results with 4 : 4-diamidino-stilbene in treating cases of kala-azar in Sudan which are notoriously difficult to treat. Similarly, Adler and Tchernomoretz (1941) treated experimentally infected Syrian hamsters with diamidino-stilbene and showed that infection due to *L. infantum* was more resistant to treatment than that due to *L. donovani*.

CUTANEOUS LEISHMANIASIS OR ORIENTAL SORE

Cutaneous leishmaniasis or oriental sore, due to *Leishmania tropica*, is common in Arab countries, in the Mediterranean Littoral, in Central Asia and in the North West Frontier of India. South American muco-cutaneous leishmaniasis, due to *Leishmania braziliensis*, differs from the oriental sore, as buccal and nasal mucous membranes may be extensively involved, in addition to the cutaneous nodules. Morphologically *L. tropica* and *L. braziliensis* appear to be similar. As in cases of visceral leishmaniasis, sandflies are regarded as the transmitting agents for cutaneous leishmaniasis.

EPIDEMIOLOGY

Latyshev and Kriukova (1943) observed that investigations carried out independently by Russian workers at the All-Union Institute of Experimental Medicine and the Turkmenistan Dermatologo-Venereological Institute confirmed the existence of two types of the disease. One is a 'rural' type occurring in sandy deserts and native villages, seasonal in incidence, and the incubation period and duration of illness are comparatively much shorter. The disease runs an acute course, with rapidly ulcerating lesions, in which parasites are scanty. Wild rodents have been proved to be the reservoir hosts for this type of disease and their burrows serve as the breeding places for the sandfly vector (*P. caucasicus* and *P. papatasii*). The other form is described as a 'urban' type of disease occurring in towns throughout the year and with a prolonged incubation period and duration of illness. The

disease runs a chronic course with retarded papular ulceration containing numerous parasites and is known as 'dry' type. This is the type most frequently met with in the Indian sub-continent occurring in cities like Delhi, Lahore and Quetta. In the absence of any knowledge of reservoir hosts for this type of disease, man is supposed to be the main source of infection. Wherever the disease occurs, sandflies (*P. papatasii* and *P. sergentii*) are common.

Parasitological expeditions in the endemic regions of Turkmenistan, Central Asia, led to the conclusion that cutaneous leishmaniasis was a typical zoonosis, and the main sources of human infections, under desert conditions, were the burrows of gerbils. A series of more than thousand gerbils, *Rhombomys opimus*, examined microscopically revealed that up to 60 per cent. of these rodents were naturally infected with cutaneous leishmaniasis. The rodents could be infected with material from human source with 100 per cent. success and the infection could be transmitted from gerbil to man (USSR Report, 1940).

Adler and Ber (1941) reported highly successful results in easily transmitting *L. tropica* infection by the bite of *P. papatasii* to five human volunteers. This was quite unlike the previous experiments carried out. They observed that the only differences were that the flies were kept at a uniform temperature of 30°C. and imbibed a suspension of flagellates in a fluid with higher salt content.

INCIDENCE AND DISTRIBUTION IN INDIA

Elkerton (1944) treated at IMH, Quetta, 458 cases from 1936 to 1939. Most of the cases came from cavalry units and other associated units, suggesting *Stomoxys calcitrans* as the possible vector. The incubation period on an average was six months.

The incidence of oriental sore among the VCOs and IORs in India during the years 1939-46 and among the same category of personnel in the Eastern Army, Fourteenth Army and ALFSEA during the years 1942-45 is given in Tables II and III respectively.

TABLE II

Incidence of oriental sore among VCOs and IORs in India Command.

Years	Admissions		Deaths		Invalids		Average constantly sick	
	Actuals	Rate per 1,000	Actuals	Rate per 1,000	Actuals	Rate per 1,000		
1939	137	1·2	...	...	...	...	7·89	0·07
1940	86	0·5	...	...	...	...	12·54	0·07
1941	155	0·5	...	...	...	...	9·38	0·03
1942	315	0·6	...	...	11	0.02	18·55	0·04
1943	178	0·2	...	...	...	...	11·50	0·02
1944	119	0·1	...	...	1	0.00	13·83	0·02
1945	147	0·2	...	...	7	0.01	6·95	0·01
1946	118	0·2	...	...	...	...	8·53	0·01

Table III

Incidence of oriental sore among VCOs and IORs in the Eastern Army, Fourteenth Army and ALFSEA (less Ceylon Command).

Years	Admissions	
	Actuals	Rate per 1,000
1942	23	0·2
1943	65	0·2
1944	12	0·03
1945	10	0·03

In the Army in India *L. tropica* was found on forty-eight occasions in a series of 1,692 cases of cutaneous sores examined bacteriologically in 1946.

Shah (1941) reported an epidemic of oriental sore in Delhi, the infection being widespread on a rocky ridge called Kala-pahar. Up to the end of 1940, 4,215 cases had been treated and it was estimated that nearly 20,000 cases occurred in Delhi during this period. *P. sergentii* was prevalent and liable to infection with the flagellates. Leishmania could be recovered from a dog having a sore on the head. Chopra (1943) reported 10 cases of oriental sore in Kasubegu, five miles from Ferozepore. Farooq and Qutubuddin (1945) observed that oriental sore has been reported from time to time from the Aurangabad district of Hyderabad. Investigations were carried out in three towns, namely Aurangabad, Jalna and Pattan and the rate of infection was found to be 4·84, 27·76 and 42·68 per 1,000, respectively. The commonest sandfly was *P. papatasii* but *P. argentipes* also occurred in fair numbers. Daver and Ahmed (1943) examined 1,262 boys and girls in Hyderabad and found that 79 were affected with oriental sore.

TREATMENT

Elkerton (1944) could cure half of his cases within three weeks at the IMH, Quetta, by scraping under a short general anaesthesia, and dressing weekly with tannic acid powder covered with vaseline gauze. Infiltration of the sores with atebrin injections was found suitable for lesions on the face and took about the same time to heal. In the Delhi epidemic reported by Shah (1941), local treatment was by scraping followed by dressing with tannic acid powder or magnesium sulphate paste. Tartar emetic 4 per cent. also gave good results. The specific treatment was with injections of trivalent or pentavalent antimony compounds. Chopra (1943) effected cure in his cases by local injection of 2 c.c. orisol (berberine sulphate solution). Sachdeva (1943) reported successful results in the treatment of oriental sore by local treatment with quinine injections at the Mayo Hospital, Lahore. Flarer

(1939) obtained good results by infiltrating the surrounding skin with solutions of atebrin.

The incidence of dermal leishmaniasis in the eastern theatre was not high among the troops. Lesions were mostly of the 'dry' type which ulcerated at a comparatively late stage. Secondary diphtheretic infection was an occasional complication in the ulcerated stage. From the military aspect the most satisfactory treatment was excision or curettage, because the patient was cured and was fit for duty in less than one month. All forms of injection therapy took longer and were less satisfactory.

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APPENDIX A

Report on Cases of Kala-azar—No. 10 IGH

INTRODUCTION

Thirteen cases of kala-azar amongst Indian troops came under observation and treatment at No. 10 IGH during July, August and September 1941.

At the outset these cases offered considerable difficulty in diagnosis as the clinical features were not similar in all cases and were different from the Indian type. Their identity was still further masked by the superimposed infection with malaria in many cases and by the temporary relief rendered by the administration of quinine. This necessitated a series of investigations including repeated widals, and blood, urine and stool cultures which were all negative. The possibility of kala-azar, however, was constantly borne in mind and efforts to investigate the cases on these lines were well rewarded by ultimately procuring positive sternal punctures for LD bodies in seven cases. Twelve cases were imported from Sudan and Eritrea where the disease was endemic (Kassala, Gedaref and Gallabat area). One case was of the Indian type having got the disease in Tippera District in Bengal where the disease was endemic. Ten cases reacted favourably to treatment, two died, mortality being 16 per cent. In all except one case the temperature was controlled by trivalent crude antimony preparation—sodium antimony tartarate in graduated doses. Stilbin (M & B 744) was only used in five cases to reinforce the cure.

CLINICAL FEATURES

These cases ran a very acute course, two cases died in about three months. The onset was not constant. In the majority of cases onset was sudden, starting with high fever coming on with rigor and vomiting. In others it was extremely insidious, the patient experiencing a feeling of malaise and being ' out of sorts ' for two to three days before getting the high fever. The further course of the temperature differed but usually conformed to one or other of the following categories :—

(i) *High Remittent Type :* The patients had either bouts of apyrexial periods varying from two to three days, or with undulations showing rise of temperature to a moderate level for a few days. Such cases simulated undulant fever.

(ii) *More or less like 'Enteric Type' :* The onset of fever was like malaria which continued for a few days. Then the temperature increased reaching 103° F. to 104° F. in a few days. This was maintained for a week or so as a high continuous, or a high remittent temperature. Then the temperature gradually fell to 100° F., 99° F. or even sometimes to normal and then showed undulation or pyrexia of low grade as in type (i). After a few days the whole cycle was repeated with the deterioration of the general condition of the patient. These attacks resembled enteric fever very closely but the characteristic features were the absence of

the typical coated tongue and toxic drowsiness of the enteric patient. In spite of the patient's weak emaciated condition and the long continued high pyrexia, he preserved a good appetite and clean tongue. Patients with a temperature of 102° F. to 103° F. were seen walking about quite unaware of their condition.

(iii) *Daily Rigor like Malaria :* The diagnosis was made more difficult in such cases by the fact that malarial parasites were found in peripheral blood and the fever did react to quinine for sometime.

(iv) *Low Intermittent Type :* (Patient running a low intermittent type of fever resembling that of mild sepsis or of tuberculosis). On an average the fever continued for eight to nine weeks before it could be controlled by the specific treatment. Except in one case at none of the stages of the disease, the temperature showed the characteristic double or treble rise in 24 hours.

Progressive loss of weight, bleeding from the gums, epistaxis, increasing appetite with poor digestion leading to intermittent attacks of diarrhoea and sometimes persistent dry cough were noted. Headache was noticeably absent in these cases.

Patients were moderately anaemic. Tongue was moist and clean and showed peculiar darkish pigmentation late in the course of the disease. There was no enlargement of lymphatic glands. Spleen was found enlarged from the beginning of the illness. It was generally firm and the enlargement was progressive. Though the tenderness on palpation was common, the patients did not complain of pain in splenic area except in one case when the large spleen was rapidly shrinking in size under treatment. Liver was not enlarged at the beginning of the disease, but later on became palpable, usually soft and sometimes tender.

Jaundice was a very prominent feature in this series of cases. Severe deep toxic jaundice was seen in 50 per cent. of cases. It was accompained by the presence of urobilin, bile salt and bile pigment in urine. Stools were of normal colour and consistency. Icteric index was 100. The jaundice appeared either early in the disease or about the fourth/fifth week. It persisted on an average from two to three weeks and then cleared up under treatment.

In all cases at some stage persistent cough, associated either with catarrhal signs in the lungs or some congestion of the bases, was noticed. There was no enlargement of lymphatic glands in any case. The blood pressure was usually low and three cases had prominent pulsation of carotids in the neck with soft systolic haemic murmur at the base of the heart. None of the cases showed any cutaneous pigmentation. Trophic changes in skin and hair, oedema and ascites which are often seen in the Indian type were observed.

The most characteristic changes in the blood picture were the leucopenia, decrease in the granulocytes and an increase in the monocytes. The usual figure varied from 2,500 to 5,000 white cells per c.mm. Polymorphs came down as low as 20 per cent. and monocytes rose up to 17 per cent. It may be of interest to mention here that one of the cases was sent labelled as 'agranulocytosis' to this hospital. Usually there was a moderate degree of microcytic hypochromic anaemia, though in

one case the RBC count was as low as 1,400,000 per c.mm. with 30 per cent. of haemoglobin (Sahli). There were a few reticulocytes. Nucleated red cells were not often found. There was a reduction in the number of platelets, the count being 200,000 per c.mm. The bleeding time and coagulation time of the blood were considerably prolonged. In some cases it was as high as 15 minutes. The erythrocyte sedimentation rate was very much increased. Aldehyde test was carried out repeatedly on these cases. It never showed a positive reaction, not even in cases who were suffering for over two months. This test does not seem to have any value to exclude the disease in this type of kala-azar.

INVESTIGATIONS

Sternal Puncture : Sternal puncture was performed by a thick bore needle after anaesthetising the area with 2 per cent. novocaine. It was positive in seven cases. LD bodies both intracellular and extracellular were seen. They were further grown on culture of N.N.N. medium in No. 7 Field Laboratory.

Gland Puncture : It was attempted in four cases with completely negative results.

Splenic Puncture : This was not attempted because—(i) even after administration of calcium for a number of days, the bleeding time and coagulation time were seen to be very prolonged, and (ii) it was considered that a large spleen would be very friable.

In two fatal cases this was attempted post-mortem and round the whole area of spleen big clots and portions of friable spleen were noticed. There was no doubt that if such a procedure had been attempted during life, patient would have died of haemorrhage and rupture of spleen.

Kahn test was negative in all cases.

Icterus index was raised. During jaundice, it was raised to about 100 units. No abnormality was discovered on repeated widals, and blood, urine and stool culture and examination of sputa and X-ray of lungs, etc.

TREATMENT

The treatment was started with crude preparation of sodium antimony tartarate. Pentavalent compound was not available from the local medical stores at the time. Later on in four cases it was reinforced by Stilbin (M & B 744). The sodium antimony tartarate was given intravenously dissolved in 10 cc. of distilled water, starting with grain $\frac{1}{2}$—and increasing by $\frac{1}{2}$ grain until the maximum dose of $1\frac{1}{2}$ grains to 2 grains was given.

The first two doses were given generally on alternate days and later doses bi-weekly. The patients tolerated them very well without any toxic symptoms. On an average, after the administration of 4 to 5 grains of the drug, the temperature came down to normal. The total amount given varied from 12 to 15 grains in cases completely cured.

Results of the treatment of these cases are given in Table I and fall under the following categories :—

(i) Cases treated with crude sodium antimony tartarate alone.
(ii) Cases treated with crude sodium antimony tartarate and later on reinforced by Stilbin. (M & B 744).

Table I gives the comparative efficiency of antimony preparations in controlling the disease.

TABLE I

Comparative efficiency of antimony compounds in controlling kala-azar.

Series	Number of cases	Number of days patient was running temperature before treatment commenced	Type of temperature†	Total amount of tartar emetic given before temperature came to normal	Total amount of tartar emetic given	Total amount of Stilbin given	Remarks
				Grains	Grains		
(i)	1	72	(i)	* 3½	12	—	Cured and discharged to duty.
	2	72	(i)	5	15	—	,, ,, ,,
	3	65	(iv)	9	12	—	,, ,, ,,
	4	35	(iv)	9	13	—	,, ,, ,,
	5	83	(iv)	3½	18	—	Cured, evacuated to India for convalescence with rapidly shrinking spleen.
	6	61	Mixed	10	20	—	,, ,, ,,
	7	64	(ii)	...	5	—	Patient died.
	8	58	(ii)	...	5	—	Patient died.
(ii)	9	25	(ii)	4½	10	2 g.	Cured, evacuated to India for convalescence with spleen rapidly shrinking.
	10	34	(ii)	9	15	1 g.	,, ,, ,,
	11	46	(ii)	9	22	1 g.	,, ,, ,,
	12	41	(ii)	4½	10	1 g.	Cured and discharged to duty.
	13*	26	(ii) Indian type.		9	2 g.	The temperature came down after 4 injections of stilbin 0·01 g. Patient evacuated to India with enlarged spleen for further treatment.

† See page 222 and 223.
* Temperature did not react to antimony treatment.

From Table I it will be observed that larger doses of sodium antimony tartarate were required to control the temperature in cases running 'low intermittent type of fever'. The only case which failed

to react to the crude drug also belongs to this type, and curiously enough this case was one of Indian type of kala-azar. On the other hand tartar emetic has proved to be efficacious in the treatment of this variety of kala-azar. The value of this drug cannot be over-estimated and early diagnosis is very essential. Stilbin (M & B 744) was given in daily intravenous doses of 0·1 g. dissolved in 10 cc. of water.

SUMMARY AND CONCLUSIONS

(i) Sudan type of kala-azar runs a very acute course rapidly becoming fatal in about three to four months as opposed to the 'Indian type' which runs a chronic course for years.

(ii) Patients showed high remittent or enteric type of temperature with undulations associated with progressive enlargement of liver, spleen and leucopaenia with monocytosis.

(iii) Toxic jaundice had been a feature of 50 per cent. of cases. This symptom is rare in the Indian type.

(iv) The double or treble rise of temperature in 24 hours was found to be rare in the Sudan type.

(v) Cutaneous pigmentation, oedema, ascites were not seen in this type—not even before death.

(vi) Patient always had a clean tongue, good appetite and looked comparatively well. This feature was one of the most striking manifestations of the disease.

(vii) Formolgel (Aldehyde) test was of no assistance in the diagnosis of these cases. It was not positive even in cases after about three months of illness or even before death.

(viii) Sternal puncture is an easy, reliable and safe method of diagnosis.

(ix) Splenic puncture may be justifiable in early stages of the disease, but cèrtainly involves great risks in cases of two to three months duration due to the danger of rupture of a friable spleen. Besides, prolongation of bleeding and coagulation times can give rise to haemorrhage.

(x) Sodium antimony tartarate is efficacious to control the temperature and cure the patient. In well-graduated doses, it has very little toxicity.

CHAPTER XIV

Leprosy

INTRODUCTION

Leprosy is a disease of slow onset and slow development, and thus does not create any great problem during wars, nor does it affect the outcome of wars like some other acute infective diseases. All the same wars do contribute towards the spread of leprosy if they involve the sojourn of the armies from the countries where leprosy is not common in countries where the disease is endemic. In these days of global wars, this aspect of the spread of leprosy has a special significance and importance.

Even in early times wars contributed considerably towards the spread of the disease from one country to another. For example, the movement of armies played a great part in the introduction and spread of leprosy in Europe. It was first introduced into Asia Minor and Greece (about 300 B.C.) by the Persian armies ; Italy was next affected (60 B.C.) by the return of Roman soldiers from the East ; the Roman troops later introduced the disease into Spain ; and from Spain the disease was carried by the Saracens to France and to other parts of Europe.

During recent times also the effects of wars on the spread of leprosy have been noticeable. This is indicated from the number of cases of leprosy developing in the personnel of the United States armed forces who took part in the last three wars—the Spanish-American War of 1898, and World Wars I and II. Hasseltine (1940) reported 132 cases of leprosy from amongst the Spanish war veterans, and 59 from World War I admitted into the National Leprosarium, Carville, from 1921 to 1940. Faget (1944) reported the admission of 14 cases into the National Leprosarium from amongst World War II veterans, and the records of the Surgeon-General War Department, Washington, indicate that up to 1946, 28 cases of leprosy were reported amongst these veterans. Aycock and Gordon (1947) have made a detailed study of the cases amongst the veterans of the three wars, and have arrived at the following conclusions : (i) With regard to the veterans of the Spanish-American War, practically all the cases among them were from non-endemic areas of the State, and they contracted the disease while on military service in places like Cuba and Phillippines where leprosy was common. They, therefore, consider that a small outbreak of leprosy occurred in native-born Americans which can be attributed to the exposure to the disease in the course of services in the war. (ii) On the contrary, the cases amongst World War I veterans were from endemic areas of the State and possibly received their infection prior to entry into military services which were in countries where leprosy is not endemic. (iii) With regard to cases amongst World War II veterans, the situation is so far similar to World War I veterans, since all the cases have been amongst persons from endemic areas of

the States. However, there has not yet been sufficient time for leprosy contracted in foreign countries to develop, and it is expected that in the near future an appreciable number of cases of leprosy may occur amongst the veterans of World War II who served in those theatres which are foci of leprosy.

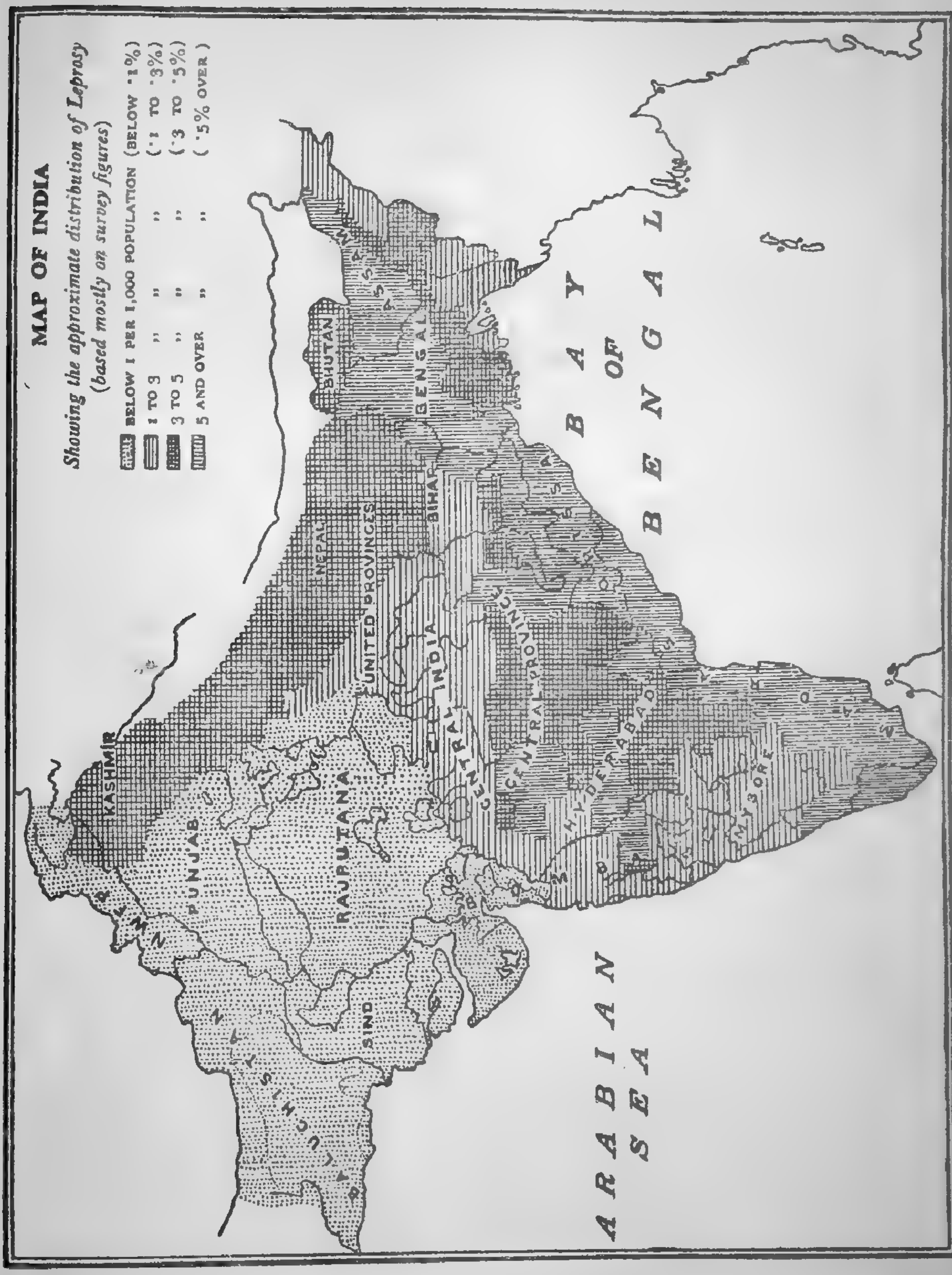
In India leprosy is endemic in many parts and, therefore, the presence of any cases of leprosy in the Indian Army may not mean that the disease is in any way connected with their service in the armed forces. The study of the subject is, however, of interest especially from the point of view of recruitment in areas where the disease was endemic. The incidence of the disease on a subsequent date in any foreign soldier who served on the Indian soil will also be of considerable interest.

The 1931 census report in India recorded 1,50,000 cases of leprosy. Investigations carried out by expert leprosy workers in different parts of the country indicate that the above figure should be multiplied by ten to get some idea of the number of cases in the country. We can, therefore, say that there are at least one million cases of leprosy in India, and even this figure may be an underestimate. The incidence of leprosy in India as a whole, therefore, roughly works out at 0·25 per cent. of the total population. This statement, has, however, to be qualified. Only 'open' cases, i.e., the cases in which leprosy bacilli can be found on routine bacteriological examination, are commonly believed to be the source of infection. For the routine examination the smears are usually made by the 'slit' method. In this method a small cut is made in the skin or nasal mucosa to the level of the dermis or sub-mucosa, and a small part of the tissue is scraped out for the purpose of making the smears. 'Closed' cases, i.e., the cases in which leprosy bacilli are not found on routine bacteriological examination by the 'slit' method, are generally considered to be non-infective. If a careful search is made in serial sections prepared from biopsy material, or if, as shown by Drs. Figueredo and Desai of Bombay, smears are made from a large piece of tissue removed by the 'clip' method, a few bacilli can be found in a large majority of such cases. Some workers, therefore, consider these cases also as potentially infective. However, the finding of a few bacilli on meticulous search has to be interpreted with great caution when the question of transmission by such cases is considered.

The total number of persons suffering from leprosy in the whole world is very roughly estimated at four to five million. It would, therefore, be apparent that India alone is responsible for about one-fifth of the total world leprosy.

Though cases of leprosy are found throughout India, the disease is not equally distributed in different parts of the country. The distribution of leprosy in India is roughly shown in the accompanying map.

The areas of high incidence of leprosy (5 or more per 1,000) are found mostly in the eastern parts, though some of them are in other areas as well. These areas include parts of Assam, West Bengal, Bihar, Orissa, Central Provinces, Madras, Travancore-Cochin and Hyderabad. In these highly endemic parts, we find large areas with incidence of 5 per cent. or more, and some individual villages with an incidence of


MAP OF INDIA
Showing the approximate distribution of Leprosy
(based mostly on survey figures)
BELOW 1 PER 1,000 POPULATION (BELOW ·1%)
1 TO 3 ,, ,, ,, (·1 TO ·3%)
3 TO 5 ,, ,, ,, (·3 TO ·5%)
5 AND OVER ,, ,, (·5% OVER)
KASHMIR
PUNJAB
RAJPUTANA
SIND
NEPAL
UNITED PROVINCES
BIHAR
BHUTAN
BENGAL
CENTRAL INDIA
CENTRAL PROVINCES
HYDERABAD
MYSORE
BAY OF BENGAL
ARABIAN SEA

15 to 20 per cent. The central and western parts of India and the Himalayan regions constitute the two main areas of moderate incidence of leprosy (1 to 5 per 1,000). These areas include parts of Bihar, United Provinces, Central India, Central Provinces, Hyderabad, Bombay and the hilly parts of the Punjab.

The north-western parts of the country constitute an area of low incidence (below 1 per 1,000). This area includes Rajputana, plains of Punjab and eastern parts of the United Provinces.

LEPROSY IN THE ARMY

Two thousand six hundred and ninety-four VCOs and IORs were invalided out of the Army during 1939-46. Invalidment due to leprosy as against total invalidments due to all causes varied from 0·53 to 3·86 per cent. There was no invalidment amongst officers due to the disease.

TABLE I

Incidence of leprosy among VCOs and IORs in the India command.

Year	Admissions	Deaths	Invalid	Average constantly sick.	Total Number invalid due to all causes	Percentage of leprosy invalid to total invalidment
1939	6	...	4	0·46	753	0·53
1940	20	...	18	1·94	2,057	0·88
1941	...	...	...	...	3,261	...
1942	...	...	...	...	6,453	...
1943	754	2	681	86·82	17,664	3·86
1944	1,160	1	948	136·35	26,472	3·58
1945	679	...	579	85·00	26,160	2·21
1946	564	1	464	81·83	18,389	2·52
Total	3,183	4	2,694	392·40	101,209	2·66

Table II sets out a detailed examination of 742 cases (27·54 per cent. of the total cases). These have been analysed according to type of leprosy and the duration of the disease. The important categories of leprosy mentioned in this series are given below :—

1. Nm2 tubd.
2. Nml tubd.
3. Nml simple
4. L2
5. Nm2 simple
6. Nml minor tubd.
7. N2
8. N1.
9. Nm2 minor tubd.
10. LI
11. Nm2 + ?L
12. Nal
13. Nm2al tubd.
14. L2Na2

TABLE II

Distribution of certain diagnosed leprosy cases in the Indian Army by duration of the disease.

Type of leprosy	Below one month	1 to 6 months	6 to 12 months	1 to 2 years	2 to 5 years	5 to 10 years	Above 10 years	Unclassified	Total
C2	...	...	...	...	...	...	...	5	5
L1	...	...	4	4	2	...	...	4	14
L2	2	15	16	11	5	...	2	10	61
L3	...	...	1	3	2	3	1	1	11
L1N1	...	...	...	...	1	...	...	1	2
L1N2	...	...	1	...	1	...	...	2	4
L2N2	...	1	1	1	1	1	...	...	5
L2Na2	1	3	1	2	...	...	...	1	8
L2Na1	...	1	...	..	...	...	...	...	1
N	...	...	...	...	...	...	...	4	4
N1	...	2	6	5	1	...	...	7	21
N2	...	1	6	9	4	1	...	3	24
N3	...	...	...	...	1	...	...	1	2
Na2	...	1	...	...	1	...	. .	...	2
Na1	1	3	1	2	1	...	...	2	10
NL1	...	...	...	1	...	...	...	...	1
N2L1	...	..	1	...	1	...	...	...	2
N2L2	...	...	...	. .	1	..	...	...	1
Nm1	...	...	...	3	...	. .	...	1	4
Nm2a1 minor tubd ...	...	1	...	...	...	. .	...	...	1
Nm2a1 Simple	...	1	2	...	...	..	.	1	4
Nm2a1 tubd	1	4	2	...	...	...	...	2	9
Nm2a2 minor tubd ...	1	...	..	...	...	...	...	...	1
Nm2a2 Simple	...	1	1	...	...	...	...	...	2
Nm2a2 tubd	..	5	...	...	...	. .	...	...	5
Nm1	...	1	...	...	...	..	...	...	1
Nm2 + ?L	2	5	4	1	...	...	...	1	13
Nm1a1 minor tubd . .	1	2	...	. .	...	...	...	1	4
Nm1a1 simple	...	1	1	1	...	...	...	...	3
Nm1a1 tubd	...	...	1	...	...	...	...	1	2
Nm1 minor	...	2	...	...	1	...	...	1	4
Nm1 minor tubd	3	21	8	1	5	...	...	1	39
Nm1 1 minor tubd... ...	...	1	1	...	...	...	...	...	2
Nm1 Nm2 minor tubd ...	...	1	...	. .	...	...	...	...	1
Nm1 Nm2 tubd	2	...	...	...	...	...	...	...	2
Nm1 simple	5	31	14	5	7	1	2	1	66
Nm1 simple arrested . .	...	...	..	1	. .	...	...	...	1
Nm1 tubd	10	31	18	7	2	...	...	6	74
Nm1 2 tubd	...	...	1	1	...	...	...	...	2
Nm1 tubd minor ...	...	1	...	...	...	...	...	...	1
Nm2 minor	...	1	...	1	...	...	...	...	2
Nm2 minor tubd	1	10	2	1	4	...	...	...	18
Nm2 simple	2	21	8	2	2	1	...	4	40
Nm2 tubd	11	35	12	7	2	3	1	4	75
Undiagnosed cases ...	5	14	4	2	1	...	...	39	65
Leprosy Total	48	217	117	71	46	10	6	104	619
No-leprosy cases	21	41	17	5	2	1	1	35	123
Total	69	258	134	76	48	11	7	139	742

There are 123 'no-leprosy' cases which form about 16·6 per cent. of the total cases. Of the 619 remaining cases, more than 50 per cent. (334) show as their duration a period of one month to one year.

Ninety cases have not been classified according to the duration of the disease. If these are excluded from our consideration, it will be seen that more than 88 per cent. of the cases are accounted for by cases which show as their duration a period up to two years.

Table III.

Distribution of certain diagnosed leprosy cases in the Indian Army by age of the patient.

Type of Leprosy	16-19 Years	20-22 Years	23-25 Years	26-28 Years	29-31 Years	32-34 Years	35-37 Years	38-40 Years	41-43 Years	44-46 Years	47-49 Years	50-52 Years	55 & over years	Unclassified	Total
C2 ...	...	...	...	...	...	...	...	1	...	...	...	...	...	4	5
L1 ...	...	...	4	4	1	1	2	...	...	...	...	...	...	2	14
L2 ...	5	13	16	8	6	2	3	2	...	...	...	1	1	4	61
L3 ...	...	...	2	2	4	1	...	1	...	...	...	1	...	...	11
L1N1 ...	1	...	...	...	...	1	...	...	...	...	...	...	...	...	2
L1N2 ...	...	...	...	4	...	...	...	...	...	...	...	...	...	...	4
L2N2 ...	...	...	2	...	...	1	1	1	...	...	...	...	...	...	5
L2Na2 ...	...	3	3	...	1	...	...	...	...	...	...	...	...	1	8
L2Na1 ...	...	...	1	...	...	...	...	...	...	...	...	...	...	...	1
N ...	...	2	1	...	...	...	...	...	...	...	...	...	...	1	4
N1 ...	...	2	5	5	2	...	2	...	...	...	...	...	...	5	21
N2 ...	2	1	5	3	4	...	2	5	...	...	...	...	...	2	24
N3 ...	...	...	...	1	...	...	...	...	...	...	...	1	...	...	2
Na2 ...	...	1	...	...	1	...	...	...	...	...	...	...	...	...	2
Na1 ...	1	2	1	3	1	1	...	1	...	...	...	...	...	...	10
NL1 ...	...	...	...	1	...	...	...	...	...	...	...	...	...	...	1
N2L1 ...	...	...	1	...	...	...	...	...	...	1	...	...	...	...	2
N2L2 ...	...	...	...	...	...	...	1	...	...	...	...	...	...	...	1
Nm1 ...	...	2	1	1	...	...	...	...	...	...	...	...	...	...	4
Nm2a1 minor tubd	...	1	...	...	...	...	...	...	...	...	...	...	...	...	1
Nm2a1 simple	...	2	2	...	...	...	...	...	...	...	...	...	...	...	4
Nm2a1 tubd	...	2	4	1	1	...	...	...	...	...	...	1	...	...	9
Nm2a2 minor tubd	...	...	...	...	...	...	1	...	...	...	...	...	...	...	1
Nm2a2 simple	...	...	1	...	...	...	...	1	...	...	...	...	...	...	2
Nm2a2 tubd	...	1	1	2	1	...	...	...	...	...	...	...	...	...	5
Nml ...	...	...	...	...	...	1	...	...	...	...	...	...	...	...	1
Nm2+?L ...	...	6	1	2	...	...	1	...	...	...	...	...	1	2	13
Nm1a1 minor tubd	...	...	2	2	...	...	...	...	...	...	...	...	...	...	4
Nm1a1 simple	...	3	...	...	...	...	...	...	...	...	...	...	...	...	3
Nm1a1 tubd	...	...	...	1	...	...	...	...	...	1	...	...	...	...	2
Nm1 minor	...	1	2	1	...	...	...	...	...	...	...	...	...	...	4
Nm1 minor tubd	6	11	5	8	7	...	1	...	...	...	...	...	1	...	39
Nm1 2 minor tubd	1	1	...	...	...	...	...	...	...	...	...	...	...	...	2
Nm1 Nm2minortubd	1	...	...	...	...	...	...	...	...	...	...	...	...	...	1
Nm1 Nm2 tubd	...	...	1	...	1	...	...	...	...	...	...	...	...	...	2
Nm1 simple	3	25	13	9	6	2	4	1	...	2	...	1	...	...	66
Nm1 simple arrested	...	...	...	1	...	...	...	...	...	...	...	...	...	...	1
Nm1 tubd	3	22	18	16	5	1	3	1	1	...	...	2	1	1	74
Nm1 2 tubd	...	2	...	...	...	...	...	...	...	...	...	...	...	...	2
Nm1 tubd minor	...	1	...	...	...	...	...	...	...	...	...	...	...	...	1
Nm2 minor	...	1	...	...	1	...	...	...	...	...	...	...	...	...	2
Nm2 minor tubd	3	6	1	3	2	1	...	1	...	...	...	1	...	...	18
Nm2 simple	5	10	12	9	4	...	...	...	...	...	...	...	...	...	40
Nm2 tubd ..	2	18	21	16	8	1	2	2	1	3	...	1	...	...	75
Undiagnosed cases	...	10	10	4	1	3	1	2	...	...	...	...	...	34	65
Leprosy Total	33	149	136	107	57	16	24	19	2	7	...	9	4	56	619
No-leprosy cases	5	27	22	29	13	5	7	4	...	3	1	1	2	4	123
TOTAL ...	38	176	158	136	70	21	31	23	2	10	1	10	6	60	742

GRAPH 1

LEPROSY AND NO-LEPROSY CASES ACCORDING TO THE DURATION OF THE DISEASE, AMONG 742 ARMY CASES REFERRED TO CIVIL LEPROSARIUMS FOR TREATMENT

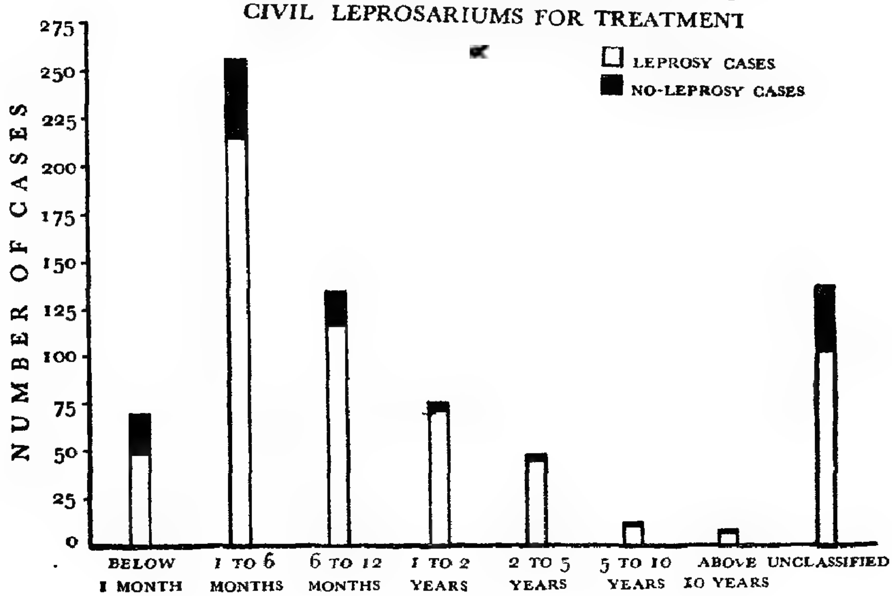
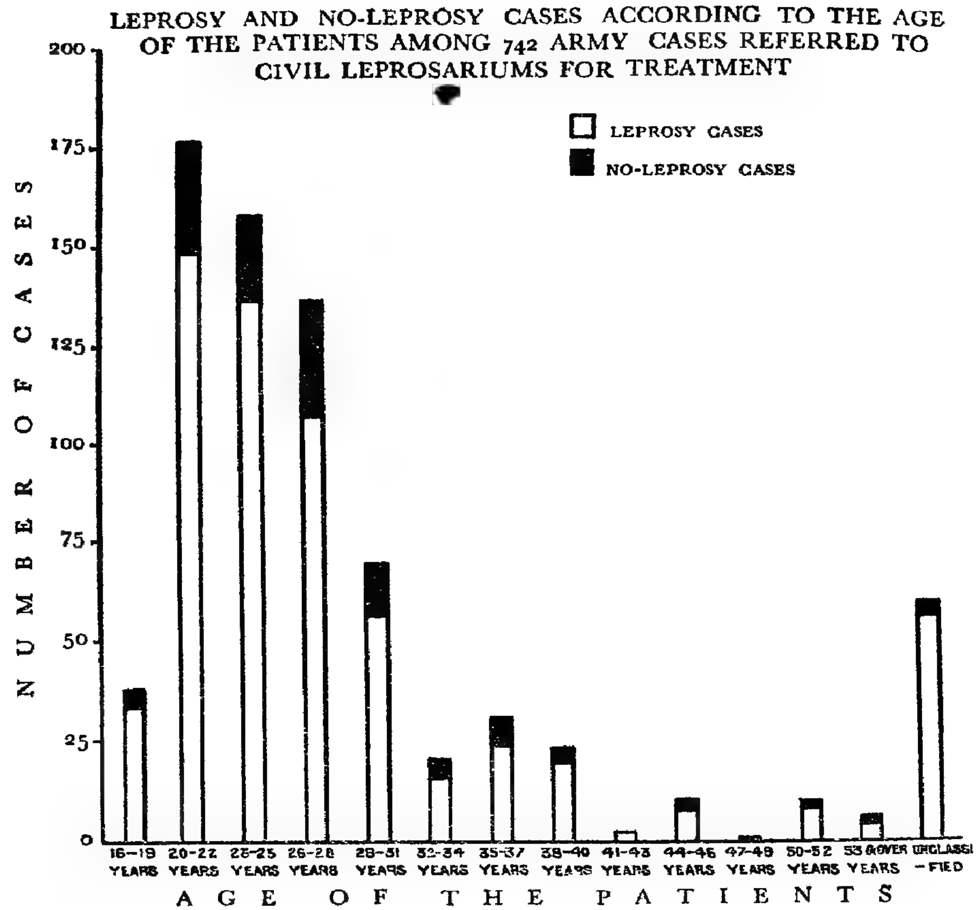


TABLE IV

Type of leprosy and percentage of cases with different duration and age-groups.

Type of leprosy	From Table II: Percentage of cases with duration up to 2 years against the total number of cases	From Table II: Percentage of cases with duration 1-6 months, 6-12 months and 1-2 years against the total	From Table III: Percentage of cases up to 31 years age against the total	From Table III: Percentage of cases having ages as 20-22 years, 23-25 years, 26-28 years, 29-31 years against the total
Nm2 tubd ...	87	72	87	84
Nm1 tubd ...	89	76	86	82
Nm1 simple ...	83	76	85	80
L2	72	69	79	70
Nm2 simple ...	83	77	100	88
Nm1 minor tubd	85	77	95	79
N2	67	67	63	54
N1	62	62	67	67
Nm2 minor tubd	78	72	83	67
L1	57	57	64	64
Nm2 + ?L ...	92	77	69	69
Na1 ...	70	60	80	70
Nm2a1 tubd ...	78	67	89	89
L2Na2 ...	88	75	87	87

GRAPH 2



It will be seen that the highest number of the leprosy cases occurred in age-groups 20 to 22, 23 to 25, and 26 to 28 years. These three groups themselves take away 68 per cent. of all classified cases. This percentage increases to about 84 if all cases up to 31 years of age are taken into account. Remembering that the age limit of recruitment varied from year to year during the war years but was in the neighbourhood of 30 years, it becomes obvious that many leprosy cases were recruited to the army undetected.

CASES EXAMINED AT SCHOOL OF TROPICAL MEDICINE, CALCUTTA

During the period of a little over five years (May 1941 to July 1946) a total of 574 cases were referred to the Leprosy Research Department, School of Tropical Medicine, Calcutta for diagnosis, mainly from the IMH, Alipore and the CMH, Barrackpur.

Statement showing regional distribution of 574 cases examined in the Leprosy Department referred by military authorities 1941-46.

Provinces	Number of cases
Madras	352
Bihar	59
United Provinces	44
Bengal	40
Punjab	33
Central Provinces	5
Gujrat	2
Orissa	1
Delhi	1
Bombay	1
Rajputana	1
Bijapur	1
Jhansi State	1
Jaipur State	1
Alwar State	1
Gwalior State	1
Jodhpur State	1
Hyderabad, Deccan	2
Cochin State	1
Burma	1
Nepal	9
Not known	16
	574

The following observations are based on the examination of these cases. The majority of the cases had their homes in South India. One hundred and seventeen of them were not found suffering from leprosy and in case of 50 definite diagnosis was not made. The 432 cases of leprosy were classified as under :—

Neural	372
Lepromatous	47
Possibly lepromatous	13
	432

The neural cases were further sub-classified as under :—

Neuro-macular simple	117
Neuro-macular minor tuberculoid	74
Neuro-macular tuberculoid	168
Neuro-anaesthetic	13
	372

BACTERIOLOGICAL FINDINGS

All the lepromatous and 'possibly lepromatous' cases were bacteriologically positive, and of the neural cases 26 were bacteriologically

positive, six from amongst the 'simple' variety and 20 from the 'tuberculoid' variety; the remaining 346 neural cases were bacteriologically negative.

Excepting in a few cases in which the disease was advanced, the disease was either slight or moderate in extent; slight in about half the cases, and moderate in the other half.

AGE-DISTRIBUTION

The age distribution of these cases of leprosy was as under :—

Below 20 years	75
20 to 25 years	180
25 to 30 years	118
Above 30 years	59
	432

It will be seen that 69 per cent. of the cases were in the age group 20-30 years, and that the remaining 31 per cent. were about equally distributed in the two age-groups below 20 and above 30. The age distribution of these cases has, no doubt, been influenced by the selective ages for recruitment to the army.

DURATION OF THE DISEASE

The duration of the disease at the time when the patients came for examination was reported to be as under :—

Below 6 months	245
6 months to 2 years	113
2 to 10 years	32
Above 10 years	6
	396*

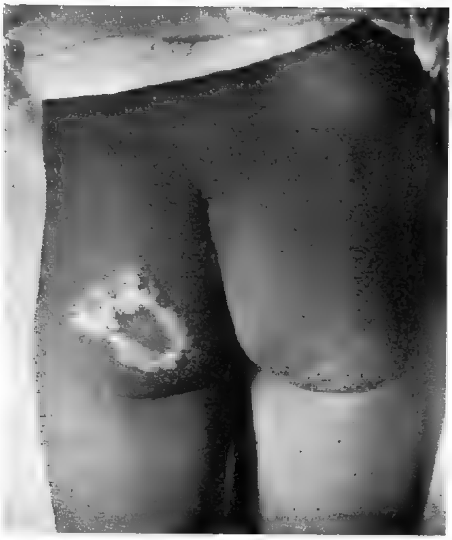
In over 60 per cent. of the cases the reported duration was below six months, and in over 90 per cent. it was below two years. This indicates that the disease in most cases was of recent origin, although the history of duration cannot be taken at its face value for various reasons, one of which is that the onset of leprosy in this country is usually insidious and the patient may not detect the presence of the disease for a considerable period.

CASES DIAGNOSED AS 'NOT LEPROSY'

One hundred and seventeen cases were found to be free from leprosy. These could be roughly divided into the two main groups, i.e., those having some skin lesions, and those complaining of some weakness, of loss of sensation, tingling in the limbs or having some deformity.

*The duration of the disease was not known in 36 cases.

1. A flat hypopigmented patch on the face. 'Simple'.



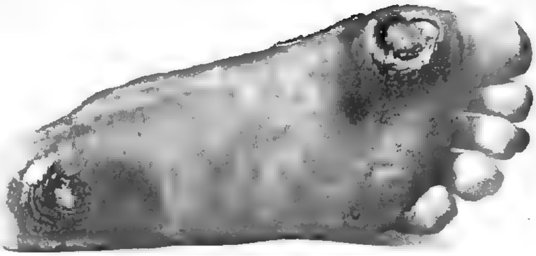
2. A patch with thick margins and flat centre on left buttock. 'Minor tuberculoid'.

3. A thick red patch on the back. 'Tuberculoid'.

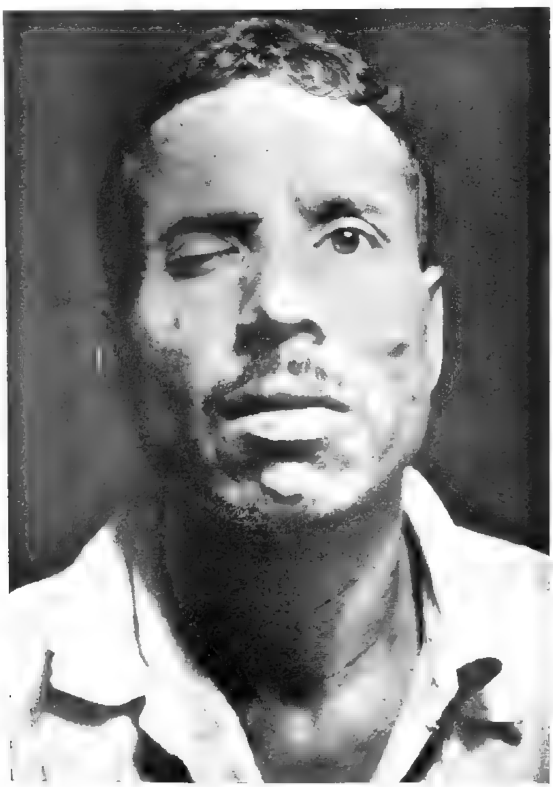
4. A thick red patch on face showing increased activity. 'Tuberculoid in stage of reaction'.

LEPROSY NEURAL TYPE

1. Deformity, hand. (There is a thick patch above elbow).

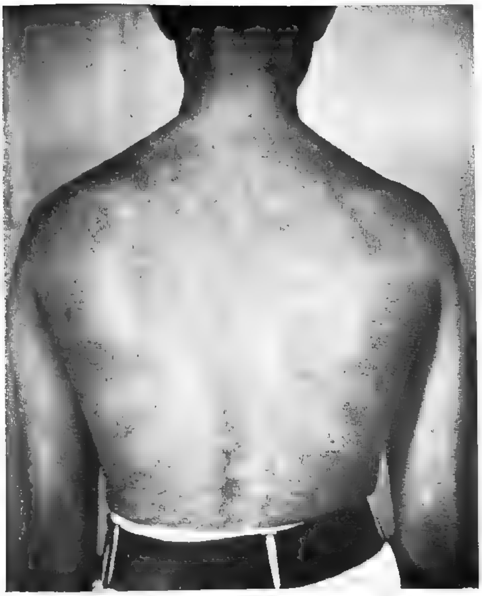


2. Trophic ulcers (foot).



3 Lagophthalmos (left eye).

LEPROSY LEPROMATOUS TYPE



1. Slight diffuse infiltration.

2. Marked diffuse infiltration.

3. Flat ill-defined patches.

LEPROSY LEPROMATOUS TYPE

1. Thick patches.

2. Infiltration and nodulation (back).

3. Infiltration and nodulation (face).

Amongst the first group were some cases which could be definitely diagnosed as cases of leucoderma, tinea, etc. In a majority of the cases, however, a definite and straightforward diagnosis of the skin condition was not possible; most of them had hypopigmented non-anaesthetic patches, others had thick erythematous non-anaesthetic patches, while a small number showed signs of some kind of dermatitis.

Amongst the cases in the second group about half complained of weakness in the extremities, vague pains and tingling. The other half complained of loss of sensation in the extremities. On testing, however, no loss of sensation was found except in one case and this was a case of Bernhardt's syndrome, i.e., neuritis of the lateral femoral cutaneous nerve.

CASES IN WHICH DEFINITE DIAGNOSIS WAS NOT POSSIBLE

In leprosy work one always comes across an occasional case in which it is not possible to make a definite diagnosis even after a thorough examination, since the signs in these cases are not definite although the appearance may be suggestive. Such cases are usually few and they are kept under observation, till either the signs become more definite and a diagnosis of leprosy is possible, or the suggestive signs disappear and it can be definitely said that the patient is not suffering from leprosy.

Amongst the cases referred from the army, the number in which a definite diagnosis was not possible has been unusually high, being 25, i.e., roughly 5 per cent. of all the cases referred for opinion. This was due to the fact that in addition to the cases in which diagnosis was not possible after a satisfactory examination, this number also included cases in which a satisfactory examination was not possible.

SOURCES OF INFECTION

Because the duration of the disease was reported to be very short in most of the cases, the question might as well be posed whether the disease was acquired during service in the army. The facts that most of these patients came from a part of India where leprosy is endemic, that leprosy has usually a long incubating period, and that the reported duration in most cases could possibly not be taken at its face value, would indicate that the disease was not acquired in the army. It appears that in most of the cases the disease was present at the time when they joined the army. It is, however, not impossible that the hardships of military life might have aggravated the disease in those in whom it was present before they joined the army, and might have reduced the latent period in those in whom under natural course of events the disease might have taken longer to manifest itself.

The view that in a large number of cases, leprosy was present before these persons joined the army would indicate the necessity of keeping leprosy in view while making examination of the recruits to the army and of equipping the examining medical personnel with better knowledge of leprosy.

[For treatment of leprosy see reports by Johansen and Erickson (1947), Dharmendra and Chatterjee (1948), Faget and Erickson (1948), Cochrane (1948), Hohenner (1949), and Hashimoto, Adachi, Sato and Hasegawa (1950).]

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APPENDIX A

A note on the Histo-Pathological classification and Laboratory Diagnosis of Leprosy

The following description of a system for classifying leprosy on a histological basis is based on the recommendations of the Sub-committee of the Cairo Conference of 1938 (Cairo Conference Report, 1938). This system was adopted by the laboratory of No. 40 (West African) General Hospital while stationed in India in 1944-45 and taught at the Southern Army (India) Leprosy courses during 1945.

PRIMARY CLASSIFICATION

Cases of leprosy can be divided histologically into the two primary groups, neural and lepromatous.

Neural (or, better, neuro-tuberculoid) leprosy is non-infective or 'closed', and lepromatous is infective or 'open' leprosy. The latter was formerly known as 'nodular' leprosy.

The essential difference between the two groups is that whereas in neural leprosy no leprosy bacilli can be demonstrated in stained dermal smears or biopsies of the skin lesions, in similar preparations from the lepromatous group, numerous leprosy bacilli can be demonstrated without difficulty. But histological differentiation between the two groups does not rely entirely on the demonstration of leprosy bacilli. The cytological and micro-anatomical differences as shown by a routine Haematoxylin-and-Biebrich-Scarlet stained biopsy may be sufficiently distinctive. Moreover, since the majority of cases of leprosy fell into the neural group, in which leprosy bacilli for practical purposes can never be demonstrated, it follows that the Haematoxylin-and-Biebrich-Scarlet preparation is of very great value, especially as with it, leprosy, irrespective of its type, may be distinguished from other skin diseases.

The two main groups can each be further sub-divided into sub-groups according to the degree and variety of the cellular response in the dermis as shown in the skin biopsy.

PATHOLOGY

The following is the course of events visualised to happen as a result of an infection with leprosy in each of the groups of patients.

Neural Leprosy: This occurs in individuals who, it is assumed, possess some native immunity against *M. leprae* and results in a vigorous cellular proliferation which effectively destroys the bacilli. Lepromatous leprosy occurs in individuals lacking native immunity to *M. leprae* and in this form there is an inadequate cellular response, with the result that bacillus, is allowed to multiply in enormous numbers in its habitat of choice, the dermis.

Pathology of Neural Leprosy : The primary portal of entry of *M. leprae* is still under dispute. It may be an abrasion in the skin, the mucous membrane of the upper respiratory passages, or even the gastro-intestinal tract.

After entry, the bacilli settle in a small primary focus, and slowly multiply. The situations of primary foci are as disputed as the portals of entry. An area of skin, a lymph node, or a nerve seem most likely.

Whatever the source of the bacilli, clinical manifestations of disease do not occur until a stimulating dose of bacilli arrives from the primary focus by way of the blood stream at the terminal capillaries of the dermis. This is usually some years after the primary infection.

The response of the partially immune skin to the arrival of an appreciable number of bacilli in its capillaries is a proliferation of the pericytes round the capillary loops of the papillary layer and those supplying the hair follicles. This appears histologically as a 'sub-epidermal perivascular and perifollicular small round-celled infiltration' [Plate VI (1)]. The picture is as yet undiagnosable as leprosy, being seen in other skin diseases, although clinically there may be a simple macule very suggestive of leprosy to the experienced observer.

Very shortly, however, the small round cells may be seen to be proliferating around and actually infiltrating the nerves. This is usually best shown in the subcutaneous tissue, where there are comparatively large neurovascular bundles, consisting of a group of medullated nerve fibres accompanied by an arteriole and venule, making the nerves easily recognisable [Plate VI (2 and 3)].

The pathognomonic feature of all forms of leprosy is the tendency to spread as an ascending nerve infection. Only when definite nerve involvement is seen may a really firm diagnosis of leprosy be made.

Soon after the nerve involvement, the epidermis begins to show trophic changes. These are hyperkeratosis, atrophy, and (in coloured races) hypopigmentation.

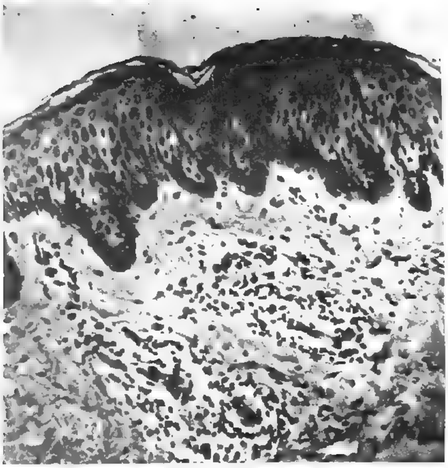
The next response of the partially immune or resistant skin is a focal mobilisation of small round cells and histiocytes. These appear as follicles or 'tubercles' in the dermis, exactly as occurs in lupus vulgaris, and as in lupus, the histiocytes in the centres of the follicles are soon replaced by, or more probably develop into, the so-called 'epithelioid' cells, larger and paler than histiocytes [Plate VI (4)].

It is from the similarity of these foci to tuberculosis that this type of leprosy gets its name 'tuberculoid leprosy'.

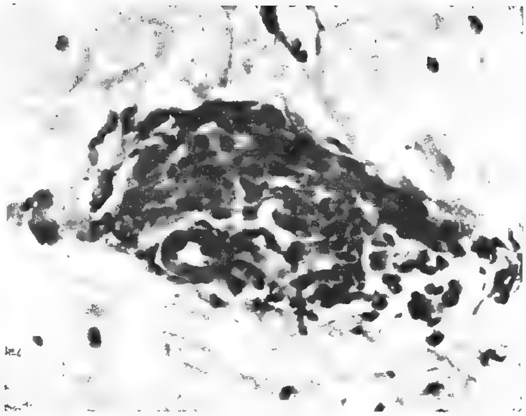
When fully developed, the leprosy 'tubercle' consists of a central zone of epithelioid cells, some of which may have fused into the form of Langhans giant cells, and a peripheral zone of small round cells or lymphocytes [Plate VII (1)].

A difference between the follicles of tuberculosis and the 'tubercles' of leprosy is that the central epithelioid cells in the tuberculosis follicle sometimes necrose, or 'caseate', while caseation has never been observed

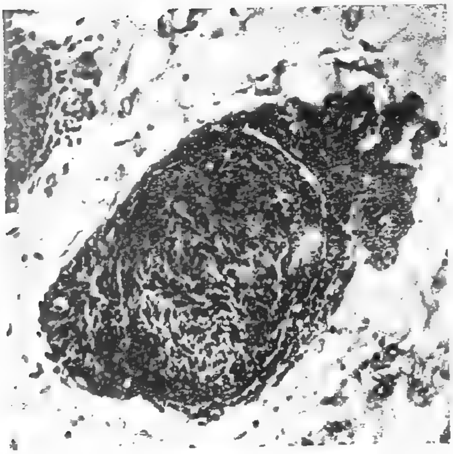
NEURAL LEPROSY



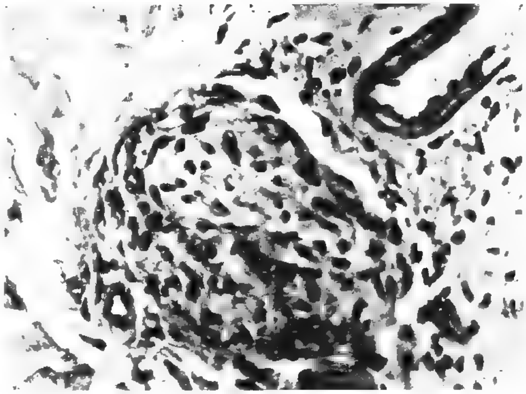
1. Sub-epidermal perivascular small round-celled infiltration.



2. Small nerve in dermal neurovascular bundle infiltrated by small round cells.

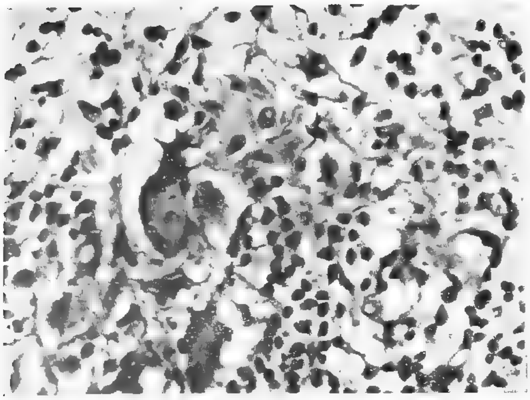


3. Larger nerve in subcutaneous fat infiltrated by small round cells.



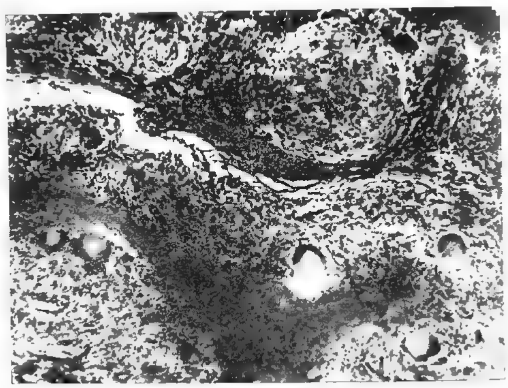
4. Small nerve in dermis almost destroyed by cellular invasion. A few epithelioid cells may be seen.

TUBERCULOID LEPROSY



1. Leprosy 'tubercle', with early giant cells.

2. Ulnar nerve, longitudinal section. Note 'tubercles', also giant cells bordering necrotic nerve fibres and giving appearance of caseation.



3. Cellular infiltration of dermis has a follicular arrangement, and there is no sub-epidermal clear zone.

in a leprosy tubercle in the dermis. In this respect, tuberculoid leprosy resembles Boeck's sarcoidosis. (However, an appearance resembling caseation may be observed in large nerve trunks in tuberculoid leprosy).

Since *M. leprae* are very quickly overcome by the tremendous cellular response of neural leprosy, the use of the Ziehl-Neelsen's stain usually fails to reveal any acid-fast bacilli and is of little positive assistance in diagnosis of this type of leprosy.

Finally, in a (successfully) immune skin, whose inflammatory cells have managed to destroy every leprosy bacillus, the process of healing begins. This takes the form of a replacement fibrosis. An increasing number of fibroblasts appear amongst the cells of the tubercles, collagen fibres are laid down, epithelioid cells and giant cells gradually disappear, and eventually there is a fibrous scar in the place of the tubercle.

It must be emphasised that the one pathognomonic feature of any leprosy is its distribution, especially its tendency to spread as an ascending nerve infection. The exact mechanism of the neural spread is not completely understood. It appears that from the capillary loops of the papillary layer of the corium and the capillaries of the hair follicles leprosy bacilli can penetrate the sheaths of the neighbouring nerve fibres and thence spread centripetally to the larger nerve trunks. The number of leprosy bacilli involved may be very small indeed, but their path is shown by the cellular response. This response will be seen to be identical with that previously described for the connective tissue of the corium, the hair follicles and sebaceous glands. Firstly, small round cells are seen around and between the nerve fibres, which become demyelinated. Then appear the histiocytes, epithelioid cells and giant cells, and soon the nerve is completely obscured and unrecognisable as such.

Occasionally, in a large nerve, the tubercles develop in such a way that the nerve necroses and the appearance of caseation is seen [Plate VII (2)]. This is the exception to the rule that the tubercles of leprosy never caseate.

Whether caseation occurs or not, the nerve fibres atrophy, fibroblasts appear, and a process of replacement fibrosis occurs. The result is a comparatively thick, fibrous cord containing leprosy tubercles or their scarred remains in the place of the bundle of nerve fibres.

The larger of the affected nerves are palpable from the stage of intraneural cellular proliferation as firm cords of perhaps three or four times the normal nerve thickness.

In the majority of cases of neural leprosy, 'tubercles' appear to be equally distributed between corium and nerves. Occasionally one sees a 'pure neural' type, in which the nerves are involved, often heavily, but no trace of dermal involvement remains. Conversely, and even more rarely, there occurs a 'pure tuberculoid' type, with dermal, but no nerve, lesions. This latter type, strictly speaking, cannot be

diagnosed histologically as leprosy, since the appearances are indistinguishable from lupus and sarcoidosis, but in the presence of a positive lepromin test, the diagnosis of leprosy may be made.

The final result of neural leprosy is complete healing, at skin and nerve level, by fibrosis. Internal organs are never affected.

Pathology of Lepromatous Leprosy : The portal of entry of the bacillus and the primary focus of infection are presumably the same in lepromatous as in neural leprosy, although no conclusive evidence has been presented.

The differing manifestations of leprosy in the two types of cases are thought to be due to a difference in the resistance of the host rather than to a difference in the virulence or mode of attack of *M. leprae.*

It is assumed in all types of leprosy that the bacilli must first reach the terminal capillaries of the skin by way of the blood stream before any signs of disease are manifested.

The response of the non-immune skin to the presence of leprosy bacilli at first bears a resemblance to the response of the partially immune skin as described above under neural leprosy, but later the picture is very different.

The earliest change seen in a section of future lepromatous skin (other than possibly a little hypopigmentation of the epidermis) is the appearance in the dermis of an increased number of small round cells and histiocytes, but with a distribution slightly different from that of the neural type. The early lepromatous macule shows small round cells and histiocytes scattered diffusely in the corium, with no marked predilection for blood vessels and hair follicles, and no tendency to infiltrate nerves. Nerves appear normal in the usual section [Plate VIII (1)]. A number of the histiocytes may be relatively large, but otherwise normal.

Clinically, the early lepromatous macule is even more difficult to diagnose than the early neural lesion, since it may have no anaesthesia and show nothing more than a very faint diffuse erythema of the skin.

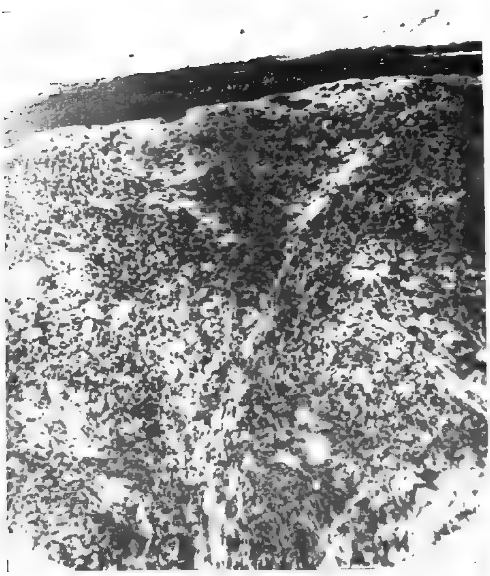
The early lepromatous macule is sometimes referred to as the ' incipient lesion of childhood '.

A Ziehl-Neelsen's stain of a section of an early lepromatous macule may, however, if careful search be made, reveal a few acid-fast bacilli. But usually the skin smear is negative and a firm diagnosis must wait.

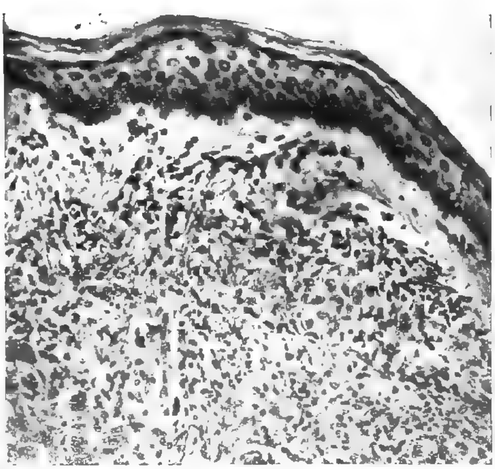
M. leprae in the non-immune skin multiply exceedingly rapidly, and the tissues seem powerless to stop them. True, histiocytes are mobilised in reasonably large numbers, forming a fairly solid granulomatous mass in the corium. There is a constant peculiarity about the distribution of these histiocytes in the corium in lepromatous leprosy, which cannot satisfactorily be explained. Instead of the infiltration spreading right up to and becoming contiguous with the basal layer of the epidermis [Plate VII (3)], there is a clear zone of perhaps 50 microns in width between the epidermis and the mass of histiocytes [Plate VIII (2)].

LEPROMATOUS LEPROSY

1. Small nerve in dermis. Cellular infiltration of nerve absent.

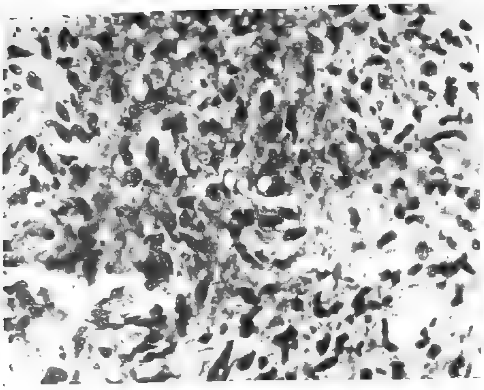


2. Cellular infiltration is diffuse. A sub-epidermal clear zone is present.

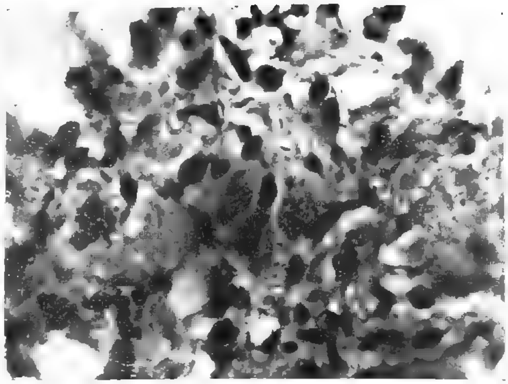


3. Dermis is infiltrated with histiocytes (lepra cells), except for sub-epidermal clear zone in which sprouting capillary can be seen. Epidermal atrophy, hyperkeratosis and hypopigmentation are also shown.

LEPROMATOUS LEPROSY

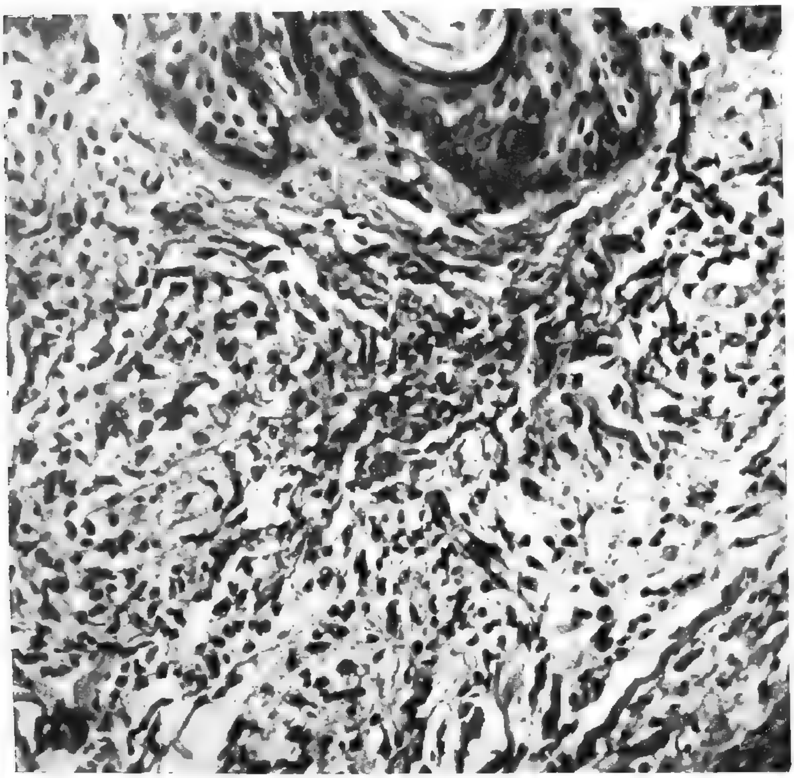


1. 'Lepra' cells. Three vacuoles (foam cells) are seen in the centre.



2. 'Lepra' cells and numerous leprosy bacilli. A 'globus' of bacilli partially fills a vacuole bottom centre.

INTERMEDIATE LEPROSY



3. Two poorly formed 'tubercles' are separated by a zone of lepra cells (centre). A sub-epidermal clear zone is present.

A Ziehl-Neelsen's stain of this section revealed a moderate number of leprosy bacilli in the central portion.

This zone contains few, if any, inflammatory cells, but often shows a number of sprouting blood capillaries [Plate VIII (3)].

The histiocytes rapidly ingest numerous bacilli by phagocytosis, but this does not stop the bacillary multiplication. Bacilli divide as easily inside the phagocytes as outside them.

Histiocytes engaged in the ingestion of leprosy bacilli are known as 'lepra' cells. In a histological section a number of them appear to contain a large vacuole, and so are sometimes called 'foam' cells [Plate IX (1)]. This vacuole may contain a tiny colony of unstained bacilli and so appear empty, but often it becomes emptied during the cutting of the section. The tiny clump, or 'globus', of bacilli originally in the vacuole falls out after passage of the microtome knife.

In addition to small round cells and plasma cells a number of mast cells may sometimes be seen amongst the lepra cells. Their significance is unknown.

A section stained by Ziehl-Neelsen's stain for acid-fast bacilli reveals very numerous leprosy bacilli situated intra- and extra cellularly amid the lepra cells, both singly and in rounded and cigar-shaped globi [Plate IX (2)]. But there still usually appear more empty lepra cells than can reasonably be accounted for by loss of bacilli during section cutting, and it must be assumed that some of the bacilli exist in a non-acid-fast form, just as is seen when a Ziehl-Neelsen's stain is made of a pure colony of tubercle bacilli.

The small round cells and histiocytes never get as far as developing into foci of epithelioid cells and giant cells in lepromatous leprosy. Only an occasional single epithelioid cell is to be seen, if any. Bacilli continue to multiply in the dermis until the whole surface of the host's body is heavily infiltrated. Eventually, wherever the patient's skin may be cut, masses of bacilli are found in the corium together with the histological appearance of lepromatous leprosy. Furthermore, bacilli invade lymphatics and may frequently be found in large numbers in lymph nodes, which appear swollen, hard, and yellowish on section, due to the presence of bacilli and lepra cells.

Blood-stream invasion may also occur, and sometimes in internal organs such as spleen, liver and bone-marrow, the bacilli are found multiplying in the cells of the reticulo-endothelial system.

M. leprae appear to be able to live as a commensal in the cells of the lepromatous patient's reticulo-endothelial system.

The testicle also often shows a fairly early swelling in lepromatous leprosy, due to the presence of bacilli and lepra cells in and around the seminiferous tubules. But on the whole, internal organs having few reticulo-endothelial cells seem to be much less liable to invasion by leprosy bacilli and show little evidence of the typical granulomatous infection.

The nerves must, of course, be excluded from the above generalisation. In lepromatous, as in neural leprosy, bacilli invade the subcutaneous nerve sheaths. They multiply and spread in a centripetal

direction between the nerve fibres. But there is no immunity and little of the cellular response of neural leprosy. On histological section, the nerve bundles, far from being obscured by cells and fibrosis, actually seem to stand out more clearly, probably due to a slight oedema and also to a proliferation of the perineurium as a result of the irritative stimulus of the rapidly multiplying bacilli.

Just as bacilli and lepra cells can pack the corium of more or less the whole external surface of the body, so also can they fill the submucosa of the nose, mouth, pharynx, larynx, trachea and larger bronchi, as well as heavily infiltrating tonsils and adenoids. From these sources it frequently happens that numerous leprosy bacilli find their way into the sputum, and, being morphologically identical with tubercle bacilli, are mistakenly diagnosed when seen in a Ziehl-Neelsen stained slide of sputum. Numerous acid-fast bacilli in sputum may be either tubercle bacilli or leprosy bacilli, a firm diagnosis being impossible purely on a Ziehl-Neelsen film, although the occurrence of numerous ovoid bundles of acid-fast bacilli, such as might have come from lepra cells, is more suggestive of lepromatous leprosy than of tuberculosis of the lungs. Intracellular acid-fast bacilli are still more suggestive of leprosy.

When acid-fast bacilli have been found in the sputum and clinical and radiological examinations are not sufficient to distinguish between tuberculosis and leprosy, diagnosis may be aided by the results of the following bacteriological tests :—

(i) Nasal smear for *M. leprae*, -positive in lepromatous leprosy, negative in tuberculosis.

(ii) Multiple skin smears for *M. leprae*, -positive in lepromatous leprosy, negative in tuberculosis.

(iii) Guinea-pig inoculation with organisms from sputum, -negative in lepromatous leprosy, positive in tuberculosis.

(iv) Tuberculin skin test (e.g. Mantoux), usually negative in lepromatous leprosy, usually positive in tuberculosis.

The lepromin test is of no assistance in this problem, as it will be negative in either case.

Lepromatous leprosy may eventually undergo spontaneous healing by fibrosis, which will destroy nerves, produce trophic changes of skin and bone, leave scars of skin, and cause fibrous atrophy of the testes, but usually, in the untreated case, death from secondary sepsis is the final result. A leproma is a good culture medium for most bacilli and cocci, and, when contaminated by secondary infection, usually necroses and becomes purulent.

Interstitial fibrosis of nerves is thus sometimes, but not often, seen in the histology of lepromatous leprosy. Sometimes the skin may also be found to be completely clear of bacilli, leaving only chronic inflammatory changes in the papillary layer with perhaps a few 'foam' cells. Lymph nodes, spleen and bone marrow may then be the only sites from which bacilli may be obtained.

INTERMEDIATE LEPROSY

Very occasionally there is seen the case with a tissue immunity intermediate between the moderately good immunity of neural leprosy and the absent immunity of lepromatous leprosy. For practical purposes these cases should be classified as lepromatous, although histologically the picture may at first sight bear a stronger resemblance to neural leprosy.

A section of the skin shows some areas of apparently typical tubercles with epithelioid cells and giant cells in the dermis, and also a marked involvement of the nerves. But on closer inspection the tubercles are seen to be inter-spersed with areas of typical lepra and 'foam' cells, and furthermore it is noticed that all granulomatous reaction both tuberculoid and lepromatous, stops short of the epidermis. There is always the characteristic clear, sometimes rather vascular zone devoid of granuloma just underneath the epidermis [Plate IX (3)]. A Ziehl-Neelsen's stain of the section shows fairly numerous acid-fast bacilli amongst the lepra cells, and a few also in the tubercles. Nerves show varying degrees of cellular involvement, but usually acid-fast bacilli are to be seen in them.

These so-called 'intermediate' cases are infective, and may develop, unless treated, into widespread lepromatous cases, although somewhat atypical. Rapid ulceration of skin is common, but prognosis is relatively good, a final healing by fibrosis being the rule. The severe scarring is the only disability remaining.

CHANGES IN THE EPIDERMIS

In all forms of leprosy, neural, lepromatous, and intermediate, from the early macules and incipient lesions to fully developed neural tuberculoid, and lepromatous patches, the epidermis shows three fairly constant changes [Plate VIII (3)] :—

(i) Hyperkeratosis, an increase in the thickness of the stratum corneum.
(ii) Atrophy, a thinning of the malpighian layer with a loss of the interpapillary processes.
(iii) Hypopigmentation (in coloured races), a decrease in the number and size of the melanin granules in the deeper layers of the stratum malpighii.

These three changes occur fairly early in the disease and are often unrelated to the size of the granuloma in the dermis. It is probable, therefore, that they are trophic changes, the result of disease of the papillary blood vessels rather than the result of mechanical pressure.

LABORATORY DIAGNOSIS

THE VALUE OF MICROSCOPICAL PREPARATIONS

The physician's clinical examination of the patient, consisting essentially of inspection of the whole body surface in a bright light,

tests of suspicious patches for anaesthesia, and palpation of the posterior auricular, ulnar and lateral popliteal nerves for tenderness and enlargement, is the most important part of the diagnosis of leprosy. But he may obtain considerable help from the pathologist in confirmation of his clinical diagnosis.

Leprosy, from the pathological point of view, is a bacterial infection of the ectoderm (skin and nerves), producing a granulomatous response. The essential manifestations of the disease, therefore, can be shown with two types of microscopical preparation of the skin : smears to demonstrate the causative acid-fast bacilli, and sections stained to show the cytology. As a rule, these two types of preparation give all the information necessary for clinical diagnosis.

Very occasionally, however, a point which the microscope fails to elucidate may be cleared up by the use of the Lepromin skin sensitivity test.

On completion of his clinical examination, the physician attempts to obtain bacteriological confirmation of the case of lepromatous, or 'open' leprosy, and histological confirmation of neural and tuberculoid leprosy.

To these ends, he takes a number of smears, ideally (but not usually practicable) from fourteen situations of each patient, and submits them to the pathological laboratory for examination.

The ideal smears are twelve taken from the skin (the lobes of both ears, both cheeks, left and right forehead, chin, both buttocks, and the edges of three suspicious places on the rest of the body), and two from the nose (taken from the left and right aspects of the nasal septum). Aspiration of enlarged lymph nodes may also prove fruitful.

Practically, however, two skin smears (from suspicious places) and one nasal must often suffice, and the three can conveniently be put on one slide.

TECHNIQUE OF SKIN SMEAR FOR *M. LEPRAE*

Phillippine Islands Method Wade (1935).

(i) Cleanse area by rubbing briefly and vigorously with cotton-wool and spirit. Dry with cotton-wool.

(ii) Pinch up skin in a fold, applying enough compression to stop or minimise bleeding. When skin cannot be picked up, compress it laterally as much as possible.

(iii) With a sterile scalpel, make a cut about 5 mm. long and at least 2 mm. deep, to get well into the infiltrated layer of the corium. If blood or lymph exudes in any quantity, wipe it off.

(iv) With the knife-blade turned transversely to the line of cut, scrape the sides and bottom of the cut repeatedly to obtain a little tissue pulp from below the epidermis.

(v) With the knife transfer some of the material to a clean microscope slide and make a moderately thick smear before the material has time to dry.

(vi) Give the patient a bit of cotton-wool to press on the cut until oozing stops. Further dressing is usually unnecessary.

TECHNIQUE OF NASAL SMEAR FOR *M. LEPRAE*

(i) In a good light, preferably using a nasal speculum, which may reveal a definite lesion, introduce a suitable instrument and scrape the median septum to remove a small piece of mucous membrane. A suitable instrument is a blunt, narrow-bladed scalpel, or a small Volkmann's spoon or curette, or even Wade's paper-clip curette (straighten out a wire paper-clip, hammer one end into a small scoop and fix the other end to a wooden handle).

(ii) Put the fragment of mucous membrane with submucosa on a clean slide, and tease it out into a smear before it dries up.

(iii) The knife and scrapers used for taking smears from one case should be flamed before using them on another, to avoid transfer of leprosy bacilli from one patient to the slides of the next patient.

TECHNIQUE OF LYMPH NODE ASPIRATION

(i) Cleanse the skin with spirit over a suitably enlarged and convenient lymph node. A superficial node of the inguinal group is usually chosen.

(ii) Immobilise the node as much as possible with a finger and thumb of one hand. With the other hard insert a sterile No. 1 hypodermic needle so that the point just penetrates the capsule of the lymph node.

(iii) Fix a well-fitting syringe to the needle, and, applying steady suction, push the point of the needle through the lymph node to its far side without emerging, and then withdraw the point to the original position just inside the lymph node. The lumen of the needle should now contain a small cylindrical biopsy whose length is the diameter of the lymph node.

(iv) Release suction on the syringe plunger and withdraw the needle and syringe together from the skin.

(v) Expel the contents of the needle into a tiny drop of clean water on a microscope slide, washing the drop in and out of the needle if necessary.

(vi) Smear the drop to a suitable thickness with the point of the needle.

TECHNIQUE OF STAINING SMEARS FOR *M. LEPRAE*

(i) Fix the smear (skin, nose, or lymph node) with heat.

(ii) Immerse the slide in cold carbol fuchsin stain (basic fuchsin 1 g., absolute alcohol 10 c.c., 5 per cent. aqueous phenol 100 c.c.) for 15 to 20 minutes.

(iii) Wash in tap water.

(iv) Decolourise in 15 per cent. sulphuric acid—approximately five minutes, followed by one minute (not more) in 95 per cent. ethyl alcohol.

Note that if overdecolourised, leprosy bacilli lose their staining properties, and the slide becomes useless.

(v) Wash well in tap water.

(vi) Counterstain with 1 per cent. aqueous methylene blue for 10 to 30 seconds.

(vii) Rinse in tap water and allow to dry.

Leprosy bacilli stain red, and if present usually appear in very large numbers, so much so that a strongly positive smear presents a red colour to the naked eye in contrast to the blue of a negative smear. Under the microscope, *M. leprae* appear as red rods about $5 \times 0{\cdot}3$ microns in size, arranged often in clumps and cigar—and egg-shaped bundles of parallel organisms. The presence of leprosy bacilli denotes lepromatous (or possibly intermediate) leprosy. It is unlikely that acid-fast bacilli found in the nose and not in the skin are *M. leprae*. Sometimes they are tubercle bacilli, more usually they are saprophytes.

Saprophytes are found to be acid-fast only, and not alcohol-fast, hence the use of 95 per cent. alcohol in the above procedure, in spite of the fact that *M. leprae*, unlike *M. tuberculosis*, is slightly decolourised by alcohol.

Confirmation of Diagnosis of Closed Types of Leprosy : If all the smears are negative for *M. leprae*, and neural or tuberculoid leprosy is a possibility, biopsies are taken from the edges of suspicious lesions.

TECHNIQUE OF SKIN BIOPSY

(i) Clean the skin with spirit (70 per cent. ethyl alcohol).

(ii) Give a local anaesthetic. 2 per cent. procaine in physiological saline is satisfactory. Only the minimum quantity of procaine solution required to produce anaesthesia need be used, and no anaesthetic should be injected within one inch of the proposed site of biopsy, or confusing tissue distortion may result.

(iii) With a really sharp, sterile scalpel, or a safety-razor blade held firmly in a holder, cut an elliptical biopsy, 25 mm. long, 6 mm. wide at its middle, and 12 mm. deep. The depth is the dimension usually most neglected. Cut across the edge of the lesion, aiming that two-thirds of the biopsy should include the lesion, and one-third normal skin. Take the long dimension of the biopsy transversely to the lines of nerve supply, so as to include as many nerve bundles as possible, and more to the proximal than the distal side of the lesion to include the affected parts of the nerves. Attempt to get a longer expanse of dermis than epidermis, and take subcutaneous fat with the biopsy. The shape of the biopsy is shown in Fig. 1.

SHAPE OF SKIN BIOPSY

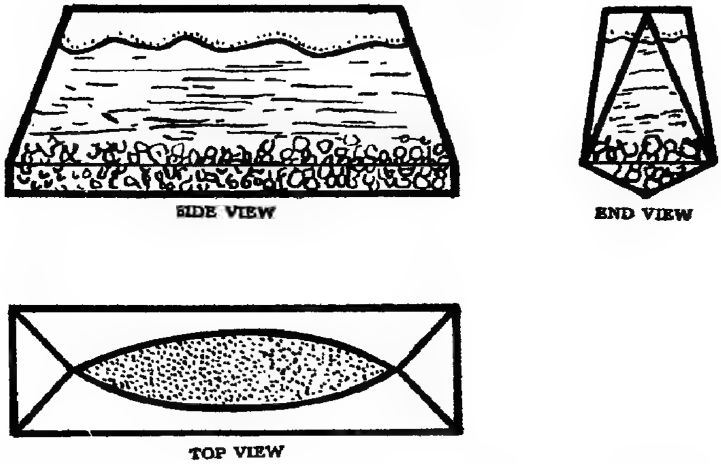


Fig. 1.

Handle the biopsy with forceps as gently as possible to avoid damage and distortion of cells by crushing.

(iv) Drop the biopsy straight into about 25 c.c. of fixing fluid in a wide-mouthed bottle, which contains a small bit of cotton-wool on which the biopsy rests. Alternatively the piece of skin may be pinned out on a cork, using rustless points, such as thorns or hedgehog quills. The biopsy will then be suspended in the fixative underneath the floating cork.

(v) Suture the biopsy site with three interrupted skin sutures.

(vi) After fixation, the biopsy is neatly trimmed with a razor-blade to a thickness of 2-3 mm.

PROCESSING OF SKIN BIOPSY

Fixing Fluids

(i) *Four per cent. Formaldehyde Saline.*

Formalin, commercial (40 per cent.)	...	1 part.
Physiological saline	...	9 parts.

Fix tissues for 24 hours or longer.

This is the most convenient fixing fluid, since tissues may be left in it indefinitely and it is easily obtained, but it suffers from the disadvantage that it causes a certain amount of distortion, and staining after this is not always good.

(ii) *Zenker's Fluid.*

Stock solutions—

A.			B.
Mercuric chloride	...	5·0 g.	Glacical acetic acid.
Potassium bichromate		2·5 g.	
Sodium sulphate		1·0 g.	
Water ...	...	100 c.c.	

Add 5 c.c. of B to 100 c.c. of A just before use.

Fix tissues for 12 to 24 hours (not longer), then wash in running water for another 24 hours.

Tissues may now be preserved, if necessary, in 70 per cent. alcohol.

This fixative causes little or no distortion and also facilitates staining.

Note that containers with aluminium lids should not be used for mercury-containing fixatives. Also, a fine precipitate of a mercury compound forms in the tissues after using these fixatives (e.g. Zenker) and this has to be removed before sections are stained. The best method is to treat the tissue at the stage of the section on the slide, after it has been brought to 70 per cent. alcohol, with a 0·5 per cent. solution of iodine in 70 per cent. alcohol for 2 minutes. This is followed by a rinse in 70 per cent. alcohol to remove most of the excess iodine, a wash in 5 per cent. aqueous sodium thiosulphate for one minute to complete the process, and finally a wash in running water for a few minutes to remove the salts. (c.f. 'Bringing Paraffin Sections to Water'). The section is now ready for staining.

Iodine solution is here made up without potassium iodide because if, as not infrequently happens in a busy operating theatre, the acetic acid is omitted from the Zenker's fluid, the tissue would be liable to proteinolysis by the iodide. On the slide, the tissue is so thin that the mercury is removed without difficulty, whereas with a block the process is much slower.

DEHYDRATING AND EMBEDDING

After fixation and washing out of the fixative, it is an advantage to treat the tissue for 24 to 48 hours in 4 per cent. aqueous phenol solution. This softens the fibrous dermis and makes the block easier to cut, thus counteracting to some extent the hardening effect of formalin (or mercuric chloride) and the brittling effect of chloroform. The phenol bath is followed by dehydration in the usual manner.

Instead of chloroform as a clearing agent, thin cedarwood oil is much preferable, as it causes no hardening, although it is not so easily replaced by paraffin. It also renders unnecessary the phenol treatment. It is, however, not always obtainable. The manner of using cedarwood oil is as follows. After fixation, the piece of skin is dehydrated with increasing strength of ethyl alcohol to absolute, transferred from absolute alcohol to a mixture of absolute alcohol and cedarwood oil, and thence to pure cedarwood oil, in which it is left until it sinks or becomes 'cleared'. The tissue may then be impregnated and blocked in paraffin wax.

Wax having a melting point of 56° C. is satisfactory in a wide variety of climates.

Skin, being denser than the average tissue, requires comparatively long treatment with paraffin for complete impregnation, especially after cedarwood oil, unless a vacuum embedding bath can be employed.

A vacuum embedding bath may be improvised simply by putting the paraffin and tissue in a test-tube in a heated water-bath, and connecting the test-tube to a suction pump.

Vacuum embedding, however, if not very carefully done, does appear sometimes to disrupt cells, although too prolonged heating in an ordinary oven has an even worse effect, often leading to severe splitting of the tissues as well as hardening.

CUTTING AND FIXATION OF SECTIONS TO SLIDES

Sections are cut at 5 to 7 microns, and fixed to slides prepared with Mayer's albumin solution.

Mayer's albumin solution :—

50 cc. fresh egg white
50 cc. glycerine
1 g. sodium salicylate.

Shake hard, stand and skim. Use the clear subjacent fluid.

To prepare slides, smear a small drop on each clean slide with the finger.

STAINING

Two slides of each specimen are brought to water. One is stained with Mayer's acid alum Haematoxylin and Biebrich Scarlet, and the other by Ziehl-Neelsen's method.

Of all the recipes for haematoxylin stain, it was found that Mayer's formula of 1891 for acid alum haematoxylin was the best for the following reasons :—

(i) It can be made up and used at once. No time is required for ripening.
(ii) It keeps for years without over-ripening.
(iii) It does not form a precipitate.
(iv) Overstaining is almost impossible with it, and differentiation with acid alcohol can usually be omitted.

Biebrich scarlet similarly was found to give a more pleasing differential stain without overstaining than did eosin.

MOUNTING

In the absence of substitutes, Canada balsam proved satisfactory. It was found that yellowing of Canada balsam with age could be prevented by painting round the edge of the cover-slip after a week with a cellulose enamel paint, thus preventing the oxidation of the balsam.

SUMMARIES OF ALTERNATIVE METHODS OF FIXING AND EMBEDDING

METHOD 1. FORMALDEHYDE FIXATION CHLOROFORM CLEARING

(Reagents more easily obtained but results not quite as satisfactory as with Method 2).

(i) 4 per cent. formaldehyde saline—48 hours at room temperature or 24 hours in 37° C. incubator.

Note : Tissues may be kept in formaldehyde saline indefinitely.

(ii) Rinse in water.
(iii) 4 per cent. aqueous phenol, 24 to 48 hours.
(iv) 70 per cent. ethyl alcohol, overnight.
(v) 95 per cent. alcohol (rectified spirit), 2 hours.
(vi) Absolute alcohol first change, 2 hours.
(vii) Absolute alcohol second change, 3 hours.
(viii) Absolute alcohol and chloroform equal parts, 1 hour.
(ix) Chloroform, overnight.
(x) Chloroform three parts with paraffin one part, 2 hours in 37°C. incubator.
(xi) Paraffin (M.P. 56°C.) first change, 3 hours in 60°C. oven.
(xii) Paraffin second change, 3 hours in 60°C. oven.
(xiii) Block.

METHOD 2. ZENKER FIXATION, CEDARWOOD OIL CLEARING

(Most satisfactory method).

(i) Zenker, 12 to 24 hours at room temperature.
(ii) Wash in running water, 12 hours.
(iii) Alcohol 70 per cent., overnight (or indefinitely).
(iv) Alcohol 95 per cent., 2 hours.
(v) Absolute alcohol first change, 2 hours.
(vi) Absolute alcohol second change, 3 hours.
(vii) Absolute alcohol and cedarwood oil for clearing equal parts, 1 hour.
(viii) Cedarwood oil, 24 hours (or longer).
(ix) Cedarwood oil three parts with paraffin one part, overnight in 37°C. incubator.
(x) Paraffin first change, 4 hours in oven at 60°C.
(xi) Paraffin second change, 4 hours in oven at 60°C.
(xii) Block.

It will be noticed that cedarwood oil is more slowly replaced by paraffin than is chloroform. A two-minute wash in Xylol instead of (ix) allows impregnation to proceed more quickly, but has an undesirable hardening effect.

BLOCKING

The blocking method found most satisfactory was the following. Half of a 7 cm. Petri dish (lid or bottom) is filled with melted and filtered paraffin. The tissue is taken from the paraffin second change with heated forceps, laid on the bottom of the Petri dish, and orientated in the cooling paraffin. Six skin sections may be arranged radially in a 7 cm. Petri dish. The small paper labels accompanying each piece of tissue are arranged in the paraffin round the edge at the same time. The surface of the paraffin is then blown upon until a firm skin of solidified paraffin has formed, and the whole dish is plunged into cold water with a sliding motion (in the

manner of inserting a photographic plate in a developing dish), to cool the wax rapidly.

When the wax is hard, the Petri dish is taken from the water and may be placed in a refrigerator for a few hours, when it will be found that the block of wax may be removed from the dish without difficulty as a result of the slight relative shrinking of the wax.

BRINGING PARAFFIN SECTIONS TO WATER (PREPARATORY TO STAINING)

(i) Dissolve out paraffin by putting slide in Xylol—2 minutes.
(ii) Remove Xylol by absolute alcohol—1 minute.
(iii) Dip in 70 per cent. alcohol.
(iv) Wash in 0·5 per cent. iodine in 70 per cent. alcohol—2 minutes.
(v) Rinse in 70 per cent. alcohol.
(vi) Wash in 5 per cent. sodium thiosulphate (aqueous)—1 minute.
(vii) Wash in running water—5 minutes.

When fixative contains no mercury salt, stages (iv) to (vii) may be omitted, and a brief rinse in water substituted for them.

SUMMARY OF STAINING METHODS FOR SECTIONS

HAEMATOXYLIN AND BIEBRICH SCARLET

Solutions :— (i) *Mayer's Acid Alum Haematoxylin.*

Sodium iodate	0·2 g.
Haematoxylin	1 g.
Citric acid	1 g.
Potassium alum	50 g.
Chloral hydrate	50 g.
Distilled water	1,000 cc.

Dissolve the haematoxylin in the water, using gentle heat. Add sodium iodate and alum. Shake occasionally until alum is dissolved. Then add citric acid and chloral.

(ii) *Biebrich Scarlet.*

Biebrich scarlet	0·5 g.
95 per cent. alcohol	16 cc.
Glycerine	4 cc.
Distilled water	200 cc.

Dissolve the stain in the alcohol, then add water and glycerine.

Method :—(i) Bring section to water.
(ii) Stain Mayer's acid alum haematoxylin, 5-15 minutes.
(iii) Blue in running tap water.
(iv) Stain with Biebrich scarlet, 5 minutes.
(v) Wash rapidly with absolute alcohol, blot with filter paper and follow quickly by.
(vi) Xylol.
(vii) Mount in Canada balsam.

ZIEHL-NEELSEN'S STAIN.

Method :—(i) Bring section to water.

(ii) Immerse in a coplin jar of cold strong carbol fuchsin solution, 1 hour.

(iii) Decolourise in 15 per cent. sulphuric acid to a faint yellow-brown.

(iv) Wash in tap water to a faint pink.

(v) Counterstain with 1 per cent. aqueous methylene blue, 2 minutes.

(vi) Rapidly wash with absolute alcohol, blot and follow quickly with

(vii) Xylol.

(viii) Mount in Canada balsam.

EXAMINATION OF HAEMATOXYLIN AND BIEBRICH SCARLET SECTION

The slide is examined systematically under the microscope for the following points :—

(i) *Hyperkeratosis of Epidermis :* An increase in thickness of the stratum corneum over that of the rest of the epidermis constitutes hyperkeratosis. This appearance is normal on weight-bearing areas, and the site from which the biopsy was taken should be known.

(ii) *Atrophy of Epidermis :* This is shown by a decrease in thickness of the stratum malpighii (prickle-cell layer), especially with flattening of the interpapillary processes.

(iii) *Hypopigmentation of Epidermis :* A localised decrease in density of melanin pigmentation contained in the deeper layers of epidermis in the area of the suspected lesion compared with the pigmentation in the epidermis of the adjacent normal skin is seen in leprosy. Complete loss of pigment in coloured races is not due entirely to leprosy. Trauma and leucoderma are the likeliest causes of localised depigmentation.

(iv) *Cellular Infiltration of Dermis :* Look for any increase in the number of cells in the dermis, and also their type and distribution.

Note :—(i) If infiltration is scanty, is it mainly perivascular or more diffuse ? If infiltration is heavier, is it follicular or diffuse ?

(ii) Note presence or absence of clear sub-epidermal zone.

Note type of infiltration, whether mainly small round cells and histiocytes or epithelioid cells and Langhans giant cells or vacuolated histiocytes (lepra and foam cells).

(iii) Are there perifollicular and perineural collections of cells ?

(iv) If perineural infiltration, have cells also invaded inside the nerve sheath ? Does the nerve bundle appear thicker or more cellular than normal ?

Examine every nerve bundle in the section, both in the dermis and subcutaneous fat. Some may be affected and some not.

(v) Is there proliferation of neurilemma nuclei of these nerves without cellular infiltration, causing the nerve to stand out clearly?

(vi) Is the nerve thickened by fibrosis, or by epithelioid and giant-celled systems ?

EXAMINATION OF THE ZIEHL-NEELSEN SECTION

Look under the oil immersion lens for red-staining, sometimes beaded, straight or slightly curved rods, 8-1 $\times$0·4—0·2 microns in size.

INTERPRETATION OF APPEARANCES

After analysis of appearances of both slides, a firm diagnosis of leprosy may be made if the following conditions are satisfied :—

(i) *Neural and Tuberculoid Leprosy.*

Haematoxylin and Biebrich Scarlet Section :

(a) There is a follicular distribution of infiltrating cells leaving no clear sub-epidermal zone. The Langhans giant cell is characteristic.

(b) There is definite presence inside a nerve bundle of infiltrating cells.

Ziehl-Neelsen Section :

No acid-fast bacilli are obvious.

(ii) *Lepromatous and Intermediate Leprosy.*

Haematoxylin and Biebrich Scarlet Section :

(a) There is a diffuse distribution of infiltrating cells, which leave a clear sub-epidermal zone. (The lepra cell is characteristic).

(b) Nerves may, or may not, appear normal.

Ziehl-Neelsen Section :

Numerous acid-fast bacilli are seen.

THE LEPROMIN TEST

The Lepromin test is a test for allergy analogous in principle to the Mantoux tuberculin test of tuberculosis.

It consists in the intradermal injection, usually into the forearm, of 0·2 cc. of an autoclaved suspension in saline of lepromatous tissue. Owing to the difficulty of growing *M. leprae* in artificial culture, lepromatous tissue from a patient is the only available concentrated source of the bacillus. Unfortunately accurate standardisation is practically impossible and hence dosage must be arbitrary.

One to three weeks after inoculation, a raised erythematous area appears in positive cases, reaching its maximum diameter (2 mm. to 8 mm.) in about four weeks.

Positive reactions are found in nearly all cases of neural and tuberculoid leprosy and in a number of apparently normal persons who have been exposed to leprosy.

The reaction is negative in all cases of lepromatous leprosy and in most cases of intermediate leprosy.

The test detects those persons possessing some immunity against the proteins of the leprosy bacillus. Its value is not in the diagnosis of leprosy, but in classification of cases of the disease, in prognosis, and in recognition of contacts.

A suitable method of preparing Lepromin is as follows :—

A number of advanced lepromatous patients, with pendulous nodular ears and large soft nodules on the body, are collected. Their fleshy nodules are dissected out, boiled in water for 20 minutes, and the water drained away. The tissue is then chopped up finely and spread out to dry in a vacuum desiccator. When dry, the tissue is ground to a powder in a mortar. (In this state it may be vacuum dried and stored indefinitely in a refrigerator). To prepare a suspension for injection, 0·4 g. of the dried powder is ground up with 10 cc. of physiological saline in a glass mortar. The upper suspension is pipetted off, the solid residue in the mortar is ground up with a fresh 10 cc. of saline, and the upper suspension added to the previous sample. This process is repeated twice. The 40 cc. of suspension obtained is then shaken well in 100 cc. stoppered measuring cylinder, and allowed to settle for ten minutes. The upper uniform suspension is again pipetted off into a second 100 cc. measuring cylinder and the sediment discarded. Finally the volume is made up to 100 cc. with physiological saline containing 0·5 per cent. phenol, and distributed into 1 cc. vaccine bottles or ampoules. These are sealed and autoclaved at 15 lbs. (120°C.) for half an hour. A rough standardisation of the suspension for comparative purposes may be made by spreading a standard loopful of the suspension (before its distribution into vaccine bottles) over a standard area of microscope slide, staining the slide, and roughly estimating the bacillary concentration. If the concentration is obviously greater than usual, a suitable dilution with phenolised saline may be made.

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The photomicrographs are all taken from biopsies performed at No. 40 (West African) General Hospital in 1944-45.

CHAPTER XV

Malaria

EFFECT OF MALARIA ON MANPOWER IN THE ARMY

The largest number of admissions in the hospitals during World War II, were due to malaria. In SEAC, malaria was the cause of nearly half of the total sickness during 1942-44 ; and at times during the transmission seasons, it accounted for more than 80 per cent. of all admissions. In Assam alone, during 1942, an official estimate of the malaria cases was 76,000. In all probability there was an under-estimation, as the statistics maintained during the chaotic period could not have been very accurate. In 1943 the incidence of malaria was officially estimated at more than double that of 1942—that is over 1,50,000 cases. The statistics in 1943, were more accurate and, allowing for the fact that there were more units involved during that year, it is doubtful, if there was any real increase in the rate over that of 1942. In the Eastern Army during 1943, out of about half a million cases admitted into medical units, over 200,000 cases were due to malaria and NYD fever. In the Arakan Campaign of 1943, malaria contributed to a large extent towards the wastage of manpower. Some units were so depleted of their entire personnel, that replacements by reinforcement had to be provided every six to eight weeks. No permanent establishment was present in such units on account of constant change of officers and men. During the spring of 1943, as much as two-thirds of the effective fighting troops in one British infantry brigade and over 30 per cent. of two battalions had to be evacuated from Arakan on account of malaria.

INCIDENCE IN THE ARMY IN INDIA

The malaria incidence (rate per 1,000 of the strength) in the Army in India since 1930 is given in Table I. From 1939 onwards, the incidence of malaria in the British Army in India steadily increased from 58·1 per 1,000 until it reached its peak figure of 248·4 per 1,000 in 1944. In 1945, however, the incidence dropped to 130·7 per 1,000 and in 1946 it touched the remarkably low figure of 34·1—an all time record, the lowest previously recorded figure being 44·5 in 1937. In 1945 there was a decrease of approximately 50 per cent. in the incidence of malaria as compared to 1944, but in 1946 the decrease was approximately 75 per cent. as compared to 1945. In the case of the Indian Army, the peak figure of 206·0 per 1,000 was reached in 1942, after which there was a steady drop to 76·1 in 1945 and 43·7 in 1946.

Preventive aspect of malaria problem is discussed in Volume on *Prevention of Diseases, Malaria Control and Nutrition.*

THE MALARIA PROBLEM
ALLIED LAND FORCES SOUTH EAST ASIA

GRAPH I

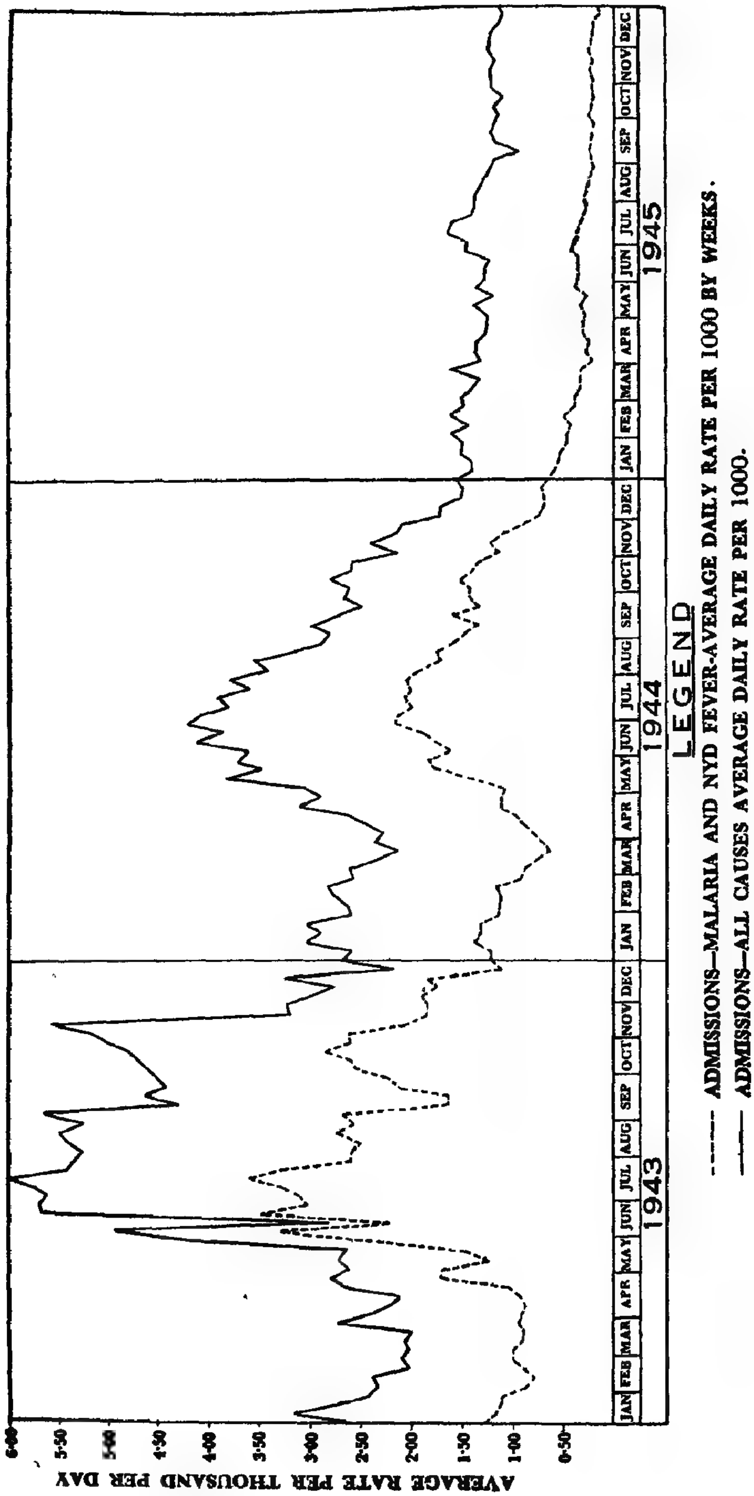


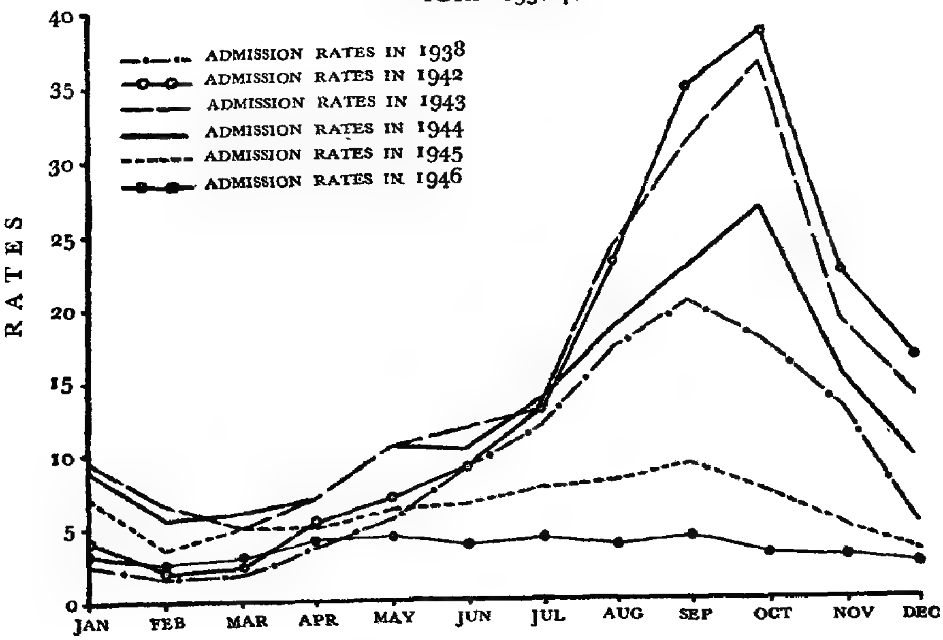
TABLE I

Malaria Incidence (rate per 1,000) in the Army in India.
(1939-46).

Year	British Army in India	Increase or decrease	Indian Army	Increase or decrease
1930	118·4	...	153·4	...
1931	112·5	–5·9	149·4	–4·0
1932	84·1	–28·4	145·1	–4·3
1933	103·3	+19·2	212·2	+67·1
1934	67·5	–35·8	156·5	–55·7
1935	56·1	–11·4	125·9	–30·6
1936	58·0	+1·9	123·1	–2·8
1937	44·5	–13·5	97·9	–25·2
1938	50·4	+5·9	109·6	+11·7
1939	58·1	+7·7	118·3	+8·7
1940	73·4	+15·3	173·2	+54·9
1941	144·4	+71·0	144·6	–28·6
1942	164·1	+19·7	206·0	+61·4
1943	198·4	+34·3	192·5	–13·5
1944	248·4	+50·0	159·5	–33·0
1945	130·7	–117·7	76·1	–83·4
1946	34·1	–96·6	43·7	–32·4

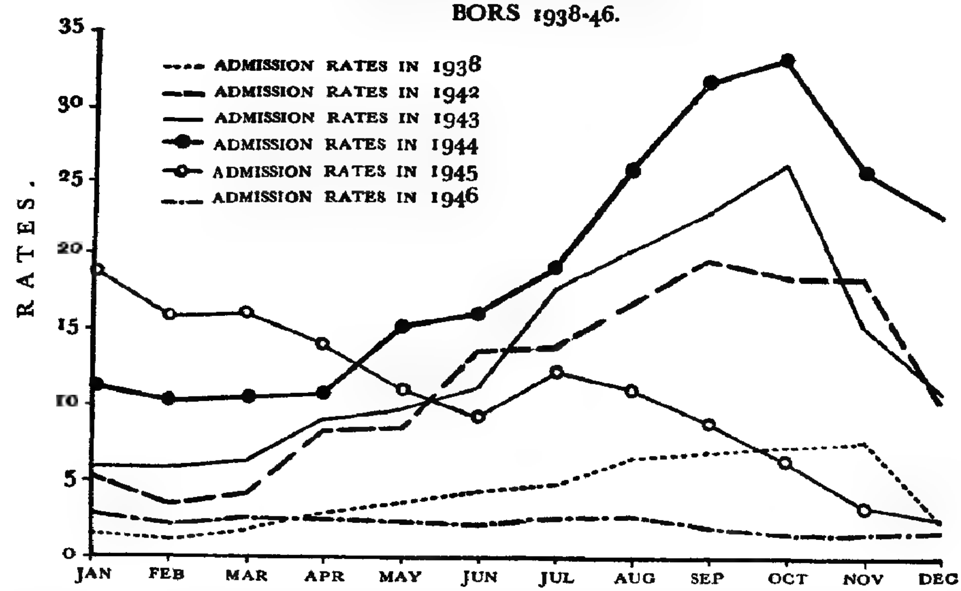
GRAPH 2

MALARIA INCIDENCE
HOSPITAL ADMISSION RATES PER 1,000 OF STRENGTH
IORs 1938-46.



GRAPH 3

MALARIA INCIDENCE
HOSPITAL ADMISSION RATES PER 1,000 OF STRENGTH
BORS 1938-46.



As can be seen from the graphs the malaria season normally starts in May/June and ends in November/December, the height of the season being reached in October/November every year. The high incidence of the disease in the first four months of 1944 and 1945 in the British troops was due to the heavy relapse rate. However, in 1946, no seasonal rise was observed either in Indian or British troops.

Of the four species of malarial parasites only two, BT and MT, caused serious anxiety. The ratio of incidence of BT to MT varied from place to place and from country to country. All-India comparative figures of different types of malaria since 1937 are given in Table II. No separate figures are available for operational areas.

TABLE II

Comparative figures (percentage) of different types of malaria among BORs in the India Command.

Year	BT	MT	Quartan	Mixed	Clinical
1937	73·00	21·32	0·95	1·80	2·94
1938	73·67	19·13	1·47	2·77	2·95
1939	70·73	24·01	0·76	1·63	2·87
1940	73·87	22·45	0·17	1·27	2·24
1941	63·02	18·45	0·12	0·77	17·64
1942	66·65	22·18	0·46	0·84	9·87
1943	68·66	17·19	0·08	0·51	13·56
1944	83·83	10·86	0·19	0·89	4·23
1945	86·44	4·44	0·16	0·52	8·44
1946	91·71	2·29	0·24	0·09	5·67

TEMPERATURE IN MALARIA

The temperature chart depended on the stage of illness at the time of admission, the nature of infection, the species of infecting parasite, the time taken for establishment of diagnosis and the initiation of and response to the specific treatment. Hunter (1945) observed four types of temperature charts in malaria patients. Type I, where no rise of temperature occurred after admission and was probably due to the patient being admitted at the end of the paroxysm of fever, further rise being prevented by the institution of treatment ; Type II, an intermittent type occurring with quotidian or tertian periodicity, more than two peaks being rare and limited to cases where diagnosis was delayed ; Type III, where a sustained fever settled down by the fifth day of treatment and Type IV, where the sustained fever persisted from the fifth to seventh day of treatment. The relative incidence of these four types as observed by him in his study of nearly 3,000 cases of fever in a hyperendemic malarial area was :—

		Percentage
Type I	...	35
Type II	...	35
Type III	...	25
Type IV	...	5

Types I and II representing the classical type of malarial fever constituted 70 per cent., and types III and IV, the atypical cases accounted for the remaining 30 per cent. Classical types of temperature were seen more often in relapses than in fresh infections, whereas the atypical types were commoner in MT than in BT infections.

SPLEEN IN MALARIA

The spleen was usually enlarged to some extent during the rigor but was not always palpable. At first the enlargement subsided during the apyrexial interval but later it tended to persist and became a permanent feature in some cases. The percentage of cases showing palpable spleen was much less in military practice than in civil, probably due to the fact that the patients in the army received an early and full course of treatment. In the series reported by Hunter (1945) nearly in two-thirds of all cases the spleen was not palpable. The rate of splenic enlargement observed in Indian troops was higher than in British troops owing to the fact that the latter came for treatment early and had few or no attacks prior to enlistment. It was a common experience to find no enlargement in spite of numerous attacks provided they were fully treated early, and to find enlargement in those cases where treatment was delayed. In other words, the splenic enlargement was related more to the period an attack remained untreated than to the actual number of attacks. In the diagnosis of active malaria a tender enlarging spleen was of more importance than a chronically enlarged and static spleen.

MALIGNANT TERTIAN MALARIA

From the point of view of clinical diagnosis and treatment, the MT was the most important. " During the war, we have learned much about MT malaria,—learned always to suspect its presence and always to treat it with respect ". (Marriott, 1945). The onset was usually sudden with shivering followed soon by feverishness. The duration of the rigor was less and the fever which was often irregular lasted longer than in other types of malaria. Severe headache, supraorbital neuralgia, backache, generalised aches and pains and frequent vomiting were commonly present. The fever, though not as persistent as a BT one, was often associated with rapid destruction of red cells leading to cachexia. Sometimes the infection remained dormant for a long period, finally manifesting in oedema of the legs, dyspepsia or some other complaints like headache, myalgia, urticaria, asthma, etc., apparently unconnected with malaria. Special clinical types of MT infection, like typhoid remittent, gastric, choleraic, dysenteric, appendicular, pulmonary, haemorrhagic and cerebral, were met with[1]. Cases with acute haemolytic anaemia rapidly progressing and simulating an advanced stage of pernicious anaemia were also reported in MT infections (Manson-Bahr, 1942). The cerebral forms were frequently met with in Assam and foot hill tracts of Burma. The infections were heavy not only due to hyperendemicity of the area or repeated infections but also to virulent nature of the parasites. Older ring forms of *P. falciparum* were frequently present in the blood and the growing trophozoites and schizonts in the peripheral blood were not uncommon in the fatal cases.

Some of the complications met with included jaundice, nephritis, peripheral neuritis, splenomegaly, anaemia, relapsing malaria and blackwater fever. A common and fatal terminal disease was pneumonia either lobar or lobular in type.

RELAPSING MALARIA

This term implies attacks of malarial fever recurring in a patient in spite of treatment and in the absence of reinfection. All forms of malaria tend to relapse and no drug which will prevent relapses in all cases has yet been discovered. Relapses do occur in MT as well as BT but the former although significant, was never a major military problem, whereas the latter assumed great importance, as nearly 50 per cent. of the cases relapsed in spite of thorough treatment. MT relapses usually occurred within six months and BT either within the first three months or between the sixth and the ninth month after the primary attack.

Shortt, Garnham, Covell and Shute (1948) demonstrated pre-erythrocytic forms of malarial parasite in the liver of an experimentally

[1] See Appendix A.

infected volunteer. The anti-malarial drugs available have none or insufficient action on this phase of the parasite so that they persist and cause relapses.

In endemic areas it was difficult in most cases, to make out if a second attack was a true relapse or due to a fresh infection. Relapsing malaria, as encountered in war time, was usually the result of multiple infection, inefficient treatment of primary attack and/or deficient immunity.

Although the problem of malarial relapses remained unsolved during the war, it was found that the patient's health was not affected to any considerable extent by BT malaria relapses, provided the attacks were immediately controlled by treatment. Some degree of splenomegaly and anaemia were seen in a small proportion of the cases ; but in a majority the patients were emotional or depressed when the objective signs were few. These cases were often benefitted by simple psychotherapy than by drugs.

BLACKWATER FEVER

A few cases of blackwater fever were seen in Assam and Bengal prior to the introduction of suppressive mepacrine ; the number, though small, was of considerable importance on account of the high mortality in improperly treated cases. In this condition, a person with a history of several insufficiently treated malarial attacks, suddenly developed acute haemolysis resulting in haemoglobinaemia and haemoglobinuria during a subsequent attack. Persons resident in hyperendemic areas for more than six months were liable to develop this disease.

In uncomplicated cases the haemoglobinuria lasted for a day or two, the renal function was not affected appreciably and the daily urinary output was not diminished. There were no toxic symptoms ; anaemia and jaundice were slight and recovery was the rule in these cases. In fulminating cases the pyrexia was marked, rigors were common and vomiting was severe. Polyuria and anaemia were more intense and the patient usually died after passing through delirium and coma. In the oliguric type there was suppression of urine, partial or complete, jaundice and vomiting were severe and urine when secreted was bile stained and loaded with albumin. Death usually occurred between fifth and tenth day and was preceded by a fall in temperature and other signs of collapse. In the continued or intermittent type haemoglobinuria continued for a long time or occurred intermittently ; the temperature remained high and jaundice and anaemia were severe ; there was no oliguria and recovery was the rule.

Mechanical blockage of the renal tubules by products of blood destruction was originally thought to be the explanation for oliguria and anuria occurring in some of these cases. But the low blood-pressure and the tissue anoxia associated with the peripheral circulatory failure seem to be more important factors and in this sense the condition is comparable to a crush syndrome or a mismatched transfusion.

MALARIA IN SURGERY

Malaria may complicate or be complicated by almost any other disease or condition. In this connection, the importance of malaria in surgical condition is worth mentioning. Malaria often contributed towards many of the unexplained fevers in the surgical wards. There was a great tendency for clinical malaria to set in after post-operative conditions, severe wounds, accidents and blood transfusion.

DIAGNOSIS OF MALARIA

The demonstration of malarial parasite in the blood and a clinical response to therapeutic administration of antimalarial drugs are the only criteria for the diagnosis of malaria. A microscopical diagnosis was not always practicable or feasible in the forward areas during the evacuation from Burma in 1942, and throughout 1943, due to the confused state of the campaign and the lack of facilities. However, with the improvement in the organisation and the supply of microscopes and other facilities to forward medical units, the percentage of cases where microscopical diagnosis was established increased rapidly with a corresponding decrease in the percentage of the 'clinical malaria' cases. The introduction of the MFTUs in 1944, where thousands of cases of malaria were diagnosed microscopically and treated, also contributed in the reduction of 'clinical malaria' in the forward areas.

Blood slides were taken invariably soon after admission in all cases of fever or cases with a history of fever unless one was certain that the entire clinical picture could adequately be explained by physical findings. Subsequently two slides were taken daily (more frequently in serious cases) until the case was diagnosed, or for three days before a diagnosis of malaria was excluded. Blood slides were also taken from all patients under treatment for some other disease where the clinical response to treatment was not adequate or when an unexpected rise of temperature occurred in the course of the disease. Blood slides were usually taken between 8 and 9 in the morning and between 12 and 1 in the afternoon, so that the results were obtained by mid-day or by evening before the medical officer left the wards. By this routine procedure the diagnosis was established early on rational lines and the treatment instituted.

In the diagnosis of cerebral malaria in an endemic area it is wise to be 'coma minded'. In wards where malaria cases were being treated, it was the practice of the medical officers to make a night round and to train their staff to be on the look out for any oddness of behaviour on the part of the patients. Thus, many cases of incipient coma were detected early and intravenous treatment was instituted which if delayed to the next morning would have been too late.

TYPES OF SLIDES AND STAINING METHODS

Thin smear well taken and stained with a good Leishman's stain gives a good picture for diagnosis but if the parasites are scanty as

in early stages or when on suppressive drug, it may take a long time to detect the parasite. This method was impracticable whenever a large number of slides had to be examined. The thick drop method has the advantage of a rapid diagnosis, although it takes nearly one hour to stain and the parasites are liable to be distorted. This method was neglected in the beginning because of the time required to stain the slide. The routine was to take a thick and thin smear and stain them both.

Field (1940) introduced a rapid method of staining the thick drop with methylene blue or brilliant cresyl blue which gave good results. This method was extensively used in the field and whenever a large number of slides had to be examined daily. The staining takes only ten seconds by this method. The sexual forms are characteristic and are readily recognised by the granules of pigment which are scattered through them. The asexual forms are less obvious. But here again, the granules of haemozoin draw attention to the large forms. Ring forms can be recognised by their shape but in cases where only this stage is present one has to resort to staining the thin smear to differentiate the species.

Later on Field (1941) introduced a modification of this stain which gave differential staining similar to that given by Leishman's stain. The method of staining is simple and quick, the whole method taking only a few seconds. Eosin is used as a counterstain in this method. On a uniform or mottled creamy-yellow background, the malarial parasite is seen with the cytoplasm stained blue and the chromatin 'dark purplish red'. The pigment is unstained and yellowish. The leucocytes present sharply defined deep blue nuclei and vaguely defined pale blue cytoplasm. The granules are well defined, large and dull red in eosinophils; and small, ill-defined and pale purple in neutrophils.

Jaswant Singh and Bhattacharji (1944) introduced a similar differential stain using two solutions. The first is a solution of methylene azure prepared under acid oxidation and subsequently dissolved in a weak solution of a strong base, e.g., caustic potash. The second solution is prepared by dissolving 1 g. of water soluble eosin in 500 c.c. of water. This method of staining takes one minute and twenty seconds for a combined thick and thin smear and 30 seconds for a thick smear only. The solutions keep well for several months and the results achieved by this method compare favourably with those obtained with any of the Romanowsky's stains.

TREATMENT OF MALARIA

Curative Treatment: Curative treatment of malaria cases in big base and garrison hospitals was satisfactory throughout 1939-45, but the same could not be said of cases treated in other medical units, especially in the forward areas in India, and on the Indo-Burma border until the end of 1943.

The factors which were responsible for this unsatisfactory state of affairs were the following :—

(i) Inadequate anti-malaria measures ;
(ii) hyperendemicity of the Indo-Burma border ;
(iii) the large number of malaria cases forming 80 per cent. of admissions during the malaria season and the high sick rate leading to non-availability of hospital beds where cases could be retained and treated in the front itself ;
(iv) complete changes in the staff every six to eight weeks ; and
(v) the confused state of the campaign.

In the beginning a man getting malaria in the field often had to go through a field ambulance, CCS, general hospital and even to a base hospital during illness and due to a constant move the treatment was far from satisfactory. One was lucky if he got back to the front in three to six months after getting an attack. However, with improvement in organisation in general and with more organised anti-malaria measures and methods of evacuation in particular in 1944-45, the state of affairs improved and the cases of uncomplicated malaria were retained at the CCS stage, with the result that patients could be rapidly cured and returned to duty. The introduction of MFTUs was a great advancement and contributed to a great extent in the reduction of manpower wastage in subsequent years. These units treated a large number of cases in forward areas and returned them to their units in two to four weeks instead of several months as happened when men got into a mammoth evacuating machine.

Before starting treatment, every effort was made to establish diagnosis by microscopical demonstration of the parasite but the importance of the laboratory establishment of diagnosis was not allowed to delay the urgently needed treatment. If possible, blood films were taken for later study. In emergencies such as the following reliance was placed upon clinical evidence :—

(i) absence of facilities for blood examination ;
(ii) severe attack although the initial blood slides were negative ;
(iii) delay in evacuation, or probability of prolonged period of transit ; and
(iv) delay in patients coming for treatment in an epidemic of MT malaria.

The decision whether treatment could be withheld pending the report of the blood rested entirely with the medical officer. Cases of ordinary severity admitted within a few hours after onset could wait for blood diagnosis to be made.

The treatment of malaria employed in the army was based in principle on the recommendation of the League of Nations Committee on Malaria, and varying combinations of quinine, atebrin and plasmoquin were used. With the fall of Java, which supplied over 90 per

cent. of the world supply of quinine, the following standard treatment was introduced in 1942 for ordinary cases.

Days 1 to 3 ...	Quinine 10 grains t.d.s., p.c.
Days 4 to 8 ...	Mepacrine 0·1 g. t.d.s., p.c.
Days 9 and 10 ...	No drug.
Days 11 to 13 ...	Pamaquin 0·01 g., b.d., p.c. for Indian troops and t.d.s., p.c. for British troops.

This treatment was found satisfactory for cases of ordinary severity and reduced the relapse rate. According to Hunter (1945), 76 per cent. of cases remained apyrexial after a completion of the second day of treatment, 20 per cent. after completing four days of treatment and only 4 per cent. were pyrexial up to the end of the seven day course. Some patients tried to evade treatment. The great scarcity of these drugs with consequent high prices facilitated their escape into civil market. A regular check of random samples of urine of patients for the absorption of these drugs was adopted to deal with this problem and whenever the negative reports were more than very occasional, the system of administration was entirely overhauled with dramatic effect.

Investigations carried out in the USA showed that the therapeutic effect of mepacrine depended on its concentration in blood plasma and it was suggested that a high dosage should be administered on the first day of treatment, so that the maximum blood level could be obtained with the least possible delay. In February 1945, the standard treatment was changed to all mepacrine treatment. Before its adoption in India, it was made the subject of a most carefully controlled large scale investigation carried out in Assam by Rogan and Coombes (1944) from May to September 1944. The new standard treatment adopted was as follows :—

Initial Treatment :—

First day :	Indian troops—0·2 g. t.d.s., p.c. British troops—0·3 g. t.d.s., p.c.
Second day :	Indian or British troops—0·2 g. t.d.s., p.c.
Third to seventh day :	Indian or British troops—0·1 g. t.d.s., p.c.

Maintenance Treatment :—

(i) If returning to an area where suppressive mepacrine was employed, 0·1 g. mepacrine daily.

(ii) If returning to an area where suppressive treatment was not employed, 0·1 g. mepacrine daily for six weeks.

This standard treatment was about as effective, if anything slightly better, in the control of fever and the abolition of parasitemia. Its main advantages were that it was shorter (a week as against a fortnight) and it avoided any break in the suppressive treatment.

Pamaquin was altogether omitted from the treatment as it was found

(i) not to have any appreciable influence in the early relapses of acute infections ;

(ii) the destruction of gametocytes which pamaquin achieved was of little importance in a hyperendemic area where there was a huge reservoir of infection in the local population ;

(iii) only a small margin of safety existed between the therapeutic and toxic doses ;

(iv) cyanosis and abdominal colic appeared in some cases ; and

(v) a few cases of haemoglobinuria were reported in patients on pamaquin treatment with fatal results.

As a result of reports received from the United Kingdom, it was decided in early part of 1945, to treat patients who have had three or more relapses of BT malaria with a ten-day course of quinine, 10 grains t.d.s., and pamaquin, 0·01 g. t.d.s., for British troops and 0·01 g. b.d., for Indian troops, given concurrently. A follow up, however, of cases treated by this method in six hospitals in the Southern Command showed that 34·2 per cent. relapsed within three months. Therefore, in September 1945, the quinine-pamaquin treatment was discontinued and relapse cases were given standard course of treatment as above followed by 0·1 g. of mepacrine daily for the remainder of their stay in India or for one year whichever was less.

Treatment of Malarial Emergencies: Special treatment is necessary very early in certain cases. These are the ' malaria emergencies ' and speed in diagnosis and treatment is necessary to lessen the risk of early fatal issue. These included :—

(i) cerebral forms ;

(ii) cardio-vascular-algid, syncopal or showing peripheral failure ;

(iii) intestinal-choleraic or dysenteric ;

(iv) haemorrhagic forms ;

(v) hyperpyrexial ; and

(vi) hyperinfection where more than 4 per cent. of red cells contained parasites or where more than 5 per cent. of the infected cells contained two or more parasites or growing forms of MT were present in the peripheral blood.

In these cases intravenous quinine was the method of choice. Intramuscular mepacrine methane sulphonate was considered the next best. Intravenous quinine or intramuscular mepacrine was also indicated where the patient could not swallow the drug or had persistent vomiting and where in spite of oral administration the temperature persisted after three to four days with asexual forms present in the blood. The standard treatment was instituted in all cases as soon as the patient could take the drug by mouth and was out of danger.

Death in cerebral malaria was often due to asphyxia and dehydration. Pulmonary oedema, falling back of the tongue and aspiration

of saliva into lungs were the main causes of asphyxia and they were prevented by constant attendance and maintenance of clear airway by means of sucker, catheter or airway tube. Dehydration occurred very rapidly in the comatose patients. Ransome, Gupta and Paterson (1944) were responsible for two important life-saving measures in the management of cerebral malaria. By nursing patients in Fowler's position, they found that it lessened coma, eased the respiration and lessened frequency of pulmonary oedema. The effects were probably brought on by the fact that the venous drainage from the brain was facilitated by the posture. The other innovation was the use of transnasal intragastric Ryle's tube as a means of continuous drip hydration and nutrition.

After-treatment of Malaria : Certain degree of anaemia was invariably present in all cases of malaria as a result of blood destruction. Investigation carried out by Rogan and Coombes (1944) in Assam, showed that it took approximately ten days from the date of admission for erythrocytes in BT malaria to regenerate to the level found on admission and thirty days for complete recovery (RBCs five million). Corresponding figures for MT malaria were twenty-five and forty days. These periods could be reduced by haematinics.

Ordinarily no special after-treatment was considered necessary except convalescence and rehabilitation in a convalescent depot for one to three weeks, where a diet rich in proteins and vegetables was given. Cases showing mild forms of anaemia were given 5 grains of ferrous sulphate thrice daily for a fortnight. Cases of severe anaemia were investigated thoroughly and proper treatment instituted. It was a common experience to find severe cases of anaemia, where malaria was the underlying aetiological factor, showing remarkable improvement in the clinical and haematological condition with a preliminary course of anti-malarial therapy.

Suppressive Treatment : Suppressive treatment is regular administration of an anti-malarial drug in small doses over a prolonged period, so as to suppress the clinical manifestations of malaria. It does not prevent infection but reduces the risk of an individual getting an attack of fever. Mepacrine was used in the prophylaxis of malaria in World War II wherever the troops were exposed to the risks of malaria. Australian group of workers under Brigadier Hamilton Fairley demonstrated the military value of the drug.

As a result of investigations in Allied countries and further practical experience in India and Burma, it was conclusively proved that mepacrine taken regularly suppresses during its period of administration a high percentage of malaria infection, both MT and BT. In addition it cures some BT cases and majority of MT infection provided it is continued for 28 days after leaving the malarious area or for 28 days after the termination of the transmission period. This treatment was given when troops were about to enter an area in which the malaria risk at the time of their entry was high and when troops, in occupation of an area liable for a high seasonal malaria incidence,

remained in the area during the whole or part of the malaria season.

It was shown in experimental groups and also in units under-field trials that when mepacrine plasma level varied between 20 to 24 micrograms per litre, there was complete suppression of malaria ; average level at which ' break throughs ' occurred ranged between 3·6 and 5 micrograms per litre. To obtain the required level for suppression, mepacrine 0·1 g. daily was started 14 days before entry into a malarious area or 14 days before the beginning of the malaria season. The regime adopted in the India Command was 2 tablets (0·2 g.) of mepacrine daily for the first seven days and thereafter one tablet (0·1 g.) daily. If the dose was missed on one day, two tablets were given the following day to maintain adequate suppressive plasma concentration. If two days were missed three tablets were given on the third day. But no further multiplication of the daily dose was permitted.

It was repeatedly shown in the field that the efficacy of the suppressive treatment depended entirely on the efficiency and regularity of administration. The failure of suppressive mepacrine in India in the early days was due to the lack of appreciation of this important factor coupled with a confused state of affairs, and poor discipline of the troops on the front at the time. The introduction of mepacrine parade under the direct supervision of an officer, the frequent examination of urine for mepacrine of those on suppressive treatment and laying of the responsibility of any ' break throughs ' on unit commanders had its remarkable effects on subsequent results. Another difficulty encountered was the spread of a rumour that mepacrine produced sterility and impotency. To counteract such rumours, a propaganda drive was instituted to explain that the drug had no deleterious effects in doses prescribed. The staining of skin due to the drug was not a serious problem.

The main objective to be obtained was to ensure that the suppressive treatment was continued for 28 days after leaving the suppressive area and that the personnel were not moved into the suppressive area for short periods such as courses at schools, without first being placed on suppressive treatment.

Thus suppressive treatment with mepacrine facilitated the troops to fight in the areas where otherwise large scale operations were almost impossible, owing to the high incidence of the disease. However, it was realised that suppressive mepacrine was only one of the several proved methods of combating malaria and its adoption should in no way preclude the concurrent employment of other measures. In fact the necessity for suppressive treatment is in itself an indication of high degree of malaria risk likely to be encountered so that personnel and unit protective measures become a matter of paramount importance.

Suppressive treatment was only instituted under order of the General Officer Commanding-in-Chief Army/Command upon the advice of the DDMS.

TOXIC EFFECTS OF ANTI-MALARIAL DRUGS

Among 49,680 cases treated with mepacrine, Bispham (1941) encountered severe vomiting, diarrhoea, anorexia, epigastric or praecardial pain, and restlessness only in 38 cases. These in a mild degree were common in the first two weeks of suppressive treatment and later on cleared up completely. Toxic psychosis of a temporary nature very rarely occurred as a result of mepacrine administration. The onset was usually sudden, about the fifth day of the commencement of treatment and lasted up to a month. Prognosis was good and recovery was the rule. States of maniac or hypomaniac excitement with euphoria, delirium, schizophrenoid symptoms, paranoid syndrome, different types of hallucinations and confusional states were all met with. Further administration of mepacrine was suspended in these cases and the recovery was usually spontaneous. Vitamin B_1 50 mg. intravenously four times a day together with large doses of B-complex by mouth and intravenous glucose were sometimes given.

Various types of skin lesions, lichenoid, eczematoid, pustular, exfoliative dermatitis or a combination of these, were met with from time to time in all theatres of the war wherever suppressive treatment was in force. In addition, hyperkeratosis of the palms and soles also occurred. The eczematoid lesions commonly occurred on the dorsal surfaces of the hand, feet, back, neck, nose and around mouth ; whereas the lichenoid lesions occurred on the trunk, axilla, groin and posterior surfaces of ears and lips. The incidence of these lesions was negligible. Mepacrine was stopped immediately and large doses of vitamins A and B complex were given. Locally potassium permanganate solution soaks were applied and systemic penicillin for secondary infections was given. The exact relation of mepacrine to these lesions is still

OTHER ANTI-MALARIAL DRUGS

Pentaquine and Isopentaquine : Pentaquine and isopentaquine were later reported to be less toxic than pamaquin.

Chloroquin : This drug, first synthesised in Germany, was tried by Americans on a large scale during the war. It controls BT fever rapidly and cures MT promptly. It is more effective than mepacrine and causes fewer gastro-intestinal symptoms. 0·6 g. initially and 0·3 g. every 6 hours for the first 24 hours, followed by 0·3 g. for four days is the recommended dosage. It is also an effective suppressive when administered once weekly (0·3 g.).

Proguanil (*Paludrine*) *:* This drug was synthesised and studied by Curd, Davey and Rose (1945) at the Imperial Chemical Industries Laboratory in England in the last year of the war. Preliminary tests carried out in England indicated that the drug is more effective and less toxic than mepacrine. Extensive trials with this drug after the war have confirmed the earlier findings. Paludrine can be used with safety to ensure complete prophylaxis against MT malaria. It has definite lethal action on the pre-erythrocytic forms of this parasite. In BT malaria it acts as a partial prophylactic only. It has a powerful schizonticidal action in both MT and BT infections. As a suppressive, it is very effective when administered once or twice a week. Although it has no effect on gametocytes as judged by morphology, parasites fail to develop in the mosquito fed on the blood of a patient taking it. Paludrine has certain additional advantages. There is very wide margin of safety between therapeutic and toxic doses and causes no discolouration of the skin. In view of the fact that it is relatively less costly, and non-toxic it can be used with safety in communities where medical supervision may not be readily available. It has in recent years replaced mepacrine in the treatment and suppression of malaria. It has, however, been recently reported that *P. vivax* and *P. falciparum* acquire resistance to proguanil.

obscure, although mepacrine is in some way responsible for their production.

Aplastic anaemia, agranulocytosis and acute hepatitis were also reported in persons on suppressive treatment (Findlay, 1947).

Pamaquin was found to be the most toxic of the three and its margin of safety was small. In therapeutic doses, normally no toxic effects were observed but epigastric pain, toxic nephritis, hepatitis, cyanosis and methaemoglobinuria have all been reported as a result of pamaquin administration during the standard army treatment and during blanket treatment. In the last group there were a few deaths. Clinically pamaquin methaemoglobinuria resembled blackwater fever.

CONCLUSION

Malaria, its treatment and control, assumed great importance with the onset of hostilities in the Far East. In the early days, the wastage of manpower on account of this disease was great and may have accounted largely for the failure of the campaigns. However, with the sad experiences gained in these early phases, well-organised malaria control measures along with thorough treatment of cases were adopted. The treatment was standardised and the anti-malarial discipline was rigidly enforced. Finally the adoption of suppressive mepacrine enabled the troops to fight in the forward areas and wastage of manpower was reduced considerably. Undoubtedly mepacrine played a major role towards victory in South East Asia.

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APPENDIX A.

Extracts from some of the typical cases.

Gastric form: Sepoy K was admitted to hospital with a history of irregular fever associated with vomiting of six days duration, symptoms coming on with rise of temperature. At the time of admission he was dehydrated, the temperature was normal and there was certain amount of epigastric tenderness. He vomited once during that day. No malarial parasites were seen in the blood. The next morning he started vomiting repeatedly, the temperature rose to 102° F. and by the evening the dehydration was so marked that he required intravenous fluids. Blood slides were examined once in two hours for malarial parasites. The first three specimens were negative but the fourth showed MT rings. He was given two intravenous injections of quinine bi-hydrochloride grains 6 at 4-hour interval followed by quinine sulphate 10 grains t. d. s. by mouth. Vomiting stopped and he made a rapid recovery.

Choleraic form: Havildar M was admitted to the hospital with a history of repeated vomiting and watery stools of about 10 hours duration. On admission he was markedly dehydrated and collapsed. The stools were watery and profuse. Examination of stools were negative for cholera. Blood-slide examination showed heavy infection with MT parasite. Immediate anti-malarial treatment (intravenous quinine therapy) in addition to replacement of fluid and chloride loss by intravenous route were instituted with dramatic improvement and subsequent uneventful recovery.

Dysenteric form: Sepoy A was admitted to hospital with a history of fever, headache and frequent stools of 48 hours duration. On examination his temperature was 102° F., his spleen was just palpable and tender, and the stools contained indefinite exudate but no pathogenic organisms were grown on subsequent culture. Blood examination revealed the presence of MT parasites and he was put on standard malaria treatment Q2, M5, P5. All his symptoms cleared up in 72 hours.

Appendicular form: Lance-Naik S was admitted to hospital with history of right-sided pain in the abdomen of about 24 hours duration. He vomited twice during this period. On admission the temperature was 100° F., pulse rate 90 per minute and tongue coated. There was rigidity and tenderness in the right ileac fossa. The case was diagnosed as acute appendicitis by the surgeon who decided on laparotomy. While the patient was being prepared, the pathologist, who had taken the blood for total and differential white cell count, reported the presence of MT parasites in the blood. The totals leucocyte count was 5,860 cmm. with a differential count of polymorphs 64 per cent., lymphocytes 25 per cent., mononucleosis 8 per cent., and eosinophils 3 per cent. On account of the presence of leucopenia and MT parasites in the blood, the operation was postponed and anti-malarial treatment with quinine was started, the patient being observed closely for further developments.

The condition cleared up rapidly within 24 to 36 hours after starting the treatment.

Pulmonary form: In two cases pulmonary signs suggested the possibility of pulmonary tuberculosis on account of repeated hemoptysis. But routine blood examination showed the presence of MT parasites and on starting the anti-malarial treatment they made rapid and complete recovery.

Haemorrhagic form: A patient was admitted with a temperature of 101·3° F. and blood slides were negative for malarial parasites on the first day of admission. The next day he had an attack of hematemesis. Blood slides showed MT parasites and anti-malarial treatment with quinine was started. He had another bout of haemorrhage few hours later and died. Unfortunately an autopsy could not be done but there was no previous history to suggest an ulcer syndrome in this case. Parry (1946) has given interesting examples of this haemorrhagic tendency in malaria, where bleeding from wounds occurred as a result of MT infection which was controlled by anti-malarial treatment.

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CHAPTER XVI

Marasmus

Marasmus means wasting and the term has been applied in a broad sense to syndromes of malnutrition. This syndrome does not appear to have been differentiated, either from the dysenteries or starvation oedema in the siege of Kut el Amara during World War I and oedema is said to have occurred among the troops captured there during their subsequent imprisonment. However, cases similar to those studied in the present investigation are common in general medical practice in India. The factors that contributed to the high incidence of the marasmus syndrome in the army were the recruitment of large number of undernourished men from the villages, conditions of service in the field where supply of fresh food was not available for long periods, the diet habits of the Indian soldier, malarial and intestinal infections by different strains of organisms for which the average Indian soldier had little or no immunity, and the conditions under which the prisoners were kept by the Axis powers.

The malnutrition syndrome was also noticed amongst the Poles in a CGH and later in an IGH in Persia and Iraq Force. The diet of these cases before admission to hospital was reported to consist of black bread and meat soup (sometimes potatoes) with practically no fresh vegetables and fruits. Clinically these cases could be divided in three groups, *viz.*, (i) wasting and absence of subcutaneous fat ; oedema and ascites due to hypo-proteinaemia; (ii) anaemia; (iii) avitaminosis (night blindness, xerophthalmia, hyperkeratosis, follicularis, xerodermia, dental caries, pellagra, fatty diarrhoea and glossitis). No genuine cases of cardiac or neuritic beri-beri or scurvy were seen. Some patients, however, did show discoloured patches on the body. Pellagra cases conformed to the text-book description with dermatitis, diarrhoea, dementia and general dysfunction of other organs of the body.

Marasmus cases were also seen amongst Indian troops in Persia and Iraq Force and Egypt. In a mixed battalion marasmus syndrome was noticed in vegetarian troops only. For months on end they were issued only dry rations and tinned milk. Quite a number of them had attack of malarial fever.

INVESTIGATIONS ON MARASMUS SYNDROME[1]

The number of marasmus cases evacuated from the Burma-Assam theatre during the difficult defensive fighting of 1942-44 is not accurately known, but was sufficiently great to make it second to malaria as a cause of manwastage in the Indian Army. At the time this investigation was planned (early 1945) the views of a number of medical officers had been

[1]This account is an abridged version of the *Report on Investigations on the Marasmus Syndrome in the Indian Soldier*. The detailed report was prepared by Lieut.-Colonel J. H. Walters, IMS, Major R. J. Rossiter, RAMC and Major H. Lehmann, RAMC.

gathered both from official and unofficial reports, but no detailed study, with laboratory facilities, had been made. The reports on the starvation in European prison camps, which had come to hand were of course not then available. In June 1945, a conference was called at GHQ to discuss research into the problem of marasmus in Indian troops. In consultation with Dr. A. Neuberger of the Medical Research Council the formation of the Marasmus Research Team as part of the GHQ Medical Research Organisation was recommended and a programme of research suggested. This was approved by the DMS India, in June 1945.

Clinical material for the investigation was to be drawn from units engaged in the anticipated Malayan Campaign and the research team was consequently organised in two components, the forward and the base. The forward or field section, consisting of a clinician and a nutrition officer, was to select suitable cases and to investigate in detail the actual dietetic conditions existing in the units in which these cases arose. The patients selected were then to be evacuated without delay to the base team working at No. 145 IBGH(IT) in Jalahali near Bangalore, where a detailed investigation with laboratory facilities would be undertaken. The capitulation of Japan necessitated a modification of the original plan, and the Base Research Team only was raised.

Lieut.-Colonel J. H. Walters was in charge of the clinical care of the patients. Major R. J. Rossiter carried out the investigation of blood and plasma volume and fat and carbohydrate tolerance tests, while Major H. Lehmann was responsible for haematology, biochemistry and gastric function tests. Captain Dhurjaty worked throughout as medical officer-in-charge of the ward in which the cases under investigation were concentrated. The plan for the repatriation of Allied prisoners provided for the accommodation of those requiring treatment in the hospitals grouped at Jalahali, and Indian patients selected from these provided the greater part of the material studied. The line of evacuation from the Burma-Malayan theatre of occupation was maintained and later many cases drawn from the occupying forces were received. This series of cases provided a very useful contrast to the repatriated prisoners.

It is convenient at this stage to sketch the aetiological background of the various syndromes found in the successive groups of returning prisoners. The standard daily ration issued by the Japanese to Indian prisoners consisted of 12 oz. rice and about 8 oz. green vegetables, usually the leaf and stem of sweet potatoes, a little tea and a small supply of sugar. Following admission to hospital this ration was automatically reduced to half. Medical supplies issued were totally inadequate, anti-malarial measures were little practised, while alimentary infections and infestations were widespread, and, in the absence of even the crudest drugs for their treatment, imposed a heavy mortality on the prisoners. The first batch of repatriated prisoners received were evacuated from Bangkok *via* Rangoon ; the men had been held for 3½ years under comparatively healthy conditions near an aerodrome, and being

on friendly terms with the Siamese, had been able to supplement their rations by the secret purchase of extra food. They were all thin but in 'hard' physical condition and provided no cases suitable for study. The next convoy was received from Singapore and most of the patients had been treated often for many months and some had been invalids for over 2 years in a large camp hospital of 3,000 beds at Neesoon village, staffed by IMS officers working under Lieut.-Colonel B. Chaudhuri with Major Elahi Bux, as officer-in-charge research section. In September 1945, there were 2,250 cases including 600 suffering from beri-beri and 250 from pulmonary tuberculosis under the care of Colonel Chaudhuri. It is recorded that a little over 17,000 cases of dysentery were treated by him in the hospital during captivity. In the hospital under his command most commendable efforts had been made to keep poultry, to grow vegetables and about 2,500 papaya trees, and success had been achieved in the production of small amounts of liver extract, for parenteral as well as oral use. Crude vitamin B group extracts were prepared from rice polishings for injections and germinating lentils (*moong dal*) for oral administration. The injections were effective parenterally, but the supply could never meet the great demand, and many of the malnutrition syndromes were present in this group of patients.

Two succeeding convoys came from Hong Kong and Canton; among these patients grave malnutrition and beri-beri were rare. The men stated that they had received fairly regular supplies of stale fish from the Japanese in addition to their basic ration and had been able to make small additional purchases from the Chinese.

The last convoys brought men repatriated from the Japanese Pacific Island bases of New Guinea and New Britain. These men, in addition to severe malnutrition had suffered severely from malaria, tuberculosis, yaws and tropical ulcers of the legs, and had been taken over in extremely poor condition by a number of Australian field medical units, at whose hands they had received excellent treatment for three months prior to their return to India.

Cases studied at the latter end of the series were drawn from units who had fought in the Burma Campaign and had subsequently been included in the forces of occupation. Their usual statement was that they were vegetarians or, if meat-eaters, had received rarely meat rations. Dried meat appears to have been regarded with much suspicion on religious grounds, and was rarely accepted by the type of patient received.

Some 2,000 patients in all were examined and from a study of these, clinical impressions were formed. In addition, a small group of 50 patients was selected, on clinical grounds only, for a more intensive investigation. This group included different types of deficiency syndrome encountered. The patients of this group also formed the subjects of the laboratory investigation described in the succeeding sections. A control group of nine Indians was also studied at the IMH, Jalahali. These were patients, otherwise healthy, who were resting after a short course of penicillin therapy for venereal diseases. They were kept in bed during the investigations.

CLINICAL FEATURES

Clinically, the cases of marasmus studied fell into five main groups, *viz.* :—

(i) Those showing marked wasting but little evidence of specific vitamin deficiency : These cases had a low blood-volume and low blood-pressure, but improved very rapidly on a high caloric diet. The incidence of such cases was about 60 per cent. of the 2,000 patients examined.

(ii) Those showing evidence of severe hypoproteinaemia with oedema and massive anasarca : These cases had a low plasma and blood-volume and plasma protein concentration (especially the albumin fraction). They responded dramatically to transfusion of concentrated plasma, which was life-saving in the most severe cases. This was a small group representing about 1 per cent. of all cases received.

(iii) Those showing syndromes considered to be due to deficiencies of vitamins of the B_2 group :—

(a) *Riboflavin Deficiency :* Characterised by angular stomatitis and cheilosis ; swelling and apical erosion of individual fungiform and filiform papillae, giving rise to an intensely sore, swollen, and magenta coloured tongue ; impaired gastric acid production and gastric motility.

(b) *Nicotinic Acid Deficiency :* The clinical features were :— loss of appetite abdominal distension after food, sometimes vomiting ; sore tongue becoming glazed at later stage but whose epithelium was markedly atrophic ; tympanites and diarrhoea with stools which showed an abnormally high fat content ; gastro-intestinal absorption, as demonstrated by the fat content and glucose tolerance tests, was impaired.

Response to specific therapy was prompt and complete in each case. The incidence of cases showing vitamin B_2 group deficiencies was approximately 10 per cent.

(iv) Those showing neurological syndromes :—

(a) *Peripheral Neuritis (Beri-beri) :* This group contained a large number of cases, approximately 20 per cent. of the whole. They recovered fairly rapidly except where muscular contractures had developed.

(b) *Captivity Cord Syndrome :* These cases frequently showed evidence of degeneration of the posterior columns, rarely of the pyramidal tracts and very occasionally of both. Such cases had a normal cerebrospinal fluid, normal fractional test meal findings and no constant changes in the blood picture. They were not usually associated with the above mentioned signs of nicotinic acid or riboflavin deficiency, or necessarily with gross wasting. A reasonable degree of recovery was seen in cases of the first type (posterior column involvement) but those showing spasticity (pyramidal tract involvement) did not improve during three months observation. Such cases formed approximately 2 per cent. of all repatriated prisoners who required hospital treatment.

1. Bilateral foot and wrist drop—peripheral neuritis (beri-beri).

2. Claw contracture—peripheral neuritis (beri-beri).

1. Flexor contracture of knees—peripheral neuritis beri-beri. (Front view).

2. Flexor contracture of knees—peripheral neuritis beri-beri. (Side view).

(c) *Captivity Amblyopia :* These were cases showing evidence of optic atrophy with localised retinal changes. This syndrome was sometimes, though not always, associated with syndromes (a) or (b). Perimetry showed marked concentric contraction of the fields of vision, but central scotoma could not be demonstrated. Considerable recovery occurred in all but the most severe cases. The incidence was about 9 per cent. of all cases examined.

(v) *Macrocytic (Nutritional) Anaemia only:* Among medical patients evacuated from the forces of occupation in the Burma-Malayan area after cessation of hostilities, many examples of gross riboflavin and nicotinic acid deficiencies have been seen, approximately 20 per cent. Among such patients cases of grave macrocytic anaemia with no evidence of other nutritional defect, were commonly encountered. The incidence of this condition was about 5 per cent.

HAEMATOLOGICAL INVESTIGATION

The repatriated Indian prisoners had anaemia, the characteristics of which were : high mean corpuscular volume (MCV), high mean corpuscular haemoglobin (MCH) and normal mean corpuscular haemoglobin concentration (MCHC). The anaemia was thus orthochromic and macrocytic. This is in contrast to the type of anaemia described in prison camps in Europe such as Belsen and Lamsdorf. The anaemia improved rapidly on treatment with liver extract injections.

GENERAL BIOCHEMICAL INVESTIGATION

The prisoners also had a low serum protein concentration. This reduction was almost entirely in the albumin fraction and hence the albumin/globulin ratio was also low. The degree of oedema was more closely related to the serum albumin than to the serum total protein concentration. In addition the serum calcium was decreased, in some cases extremely so, but there was no significant change in the serum inorganic phosphorus or serum phosphatase. There was no evidence of latent tetany. All other tests for vitamin deficiencies were negative. Such biochemical abnormalities as did occur, improved rapidly with treatment in hospital.

PLASMA VOLUME AND BLOOD VOLUME INVESTIGATION

The average plasma volume of the prisoners was lower than that of the control series, but this was of doubtful significance. The plasma volume referred to unit body-weight was, however, increased, and there was no change in the plasma volume referred to unit surface area, and a decrease when it was referred to unit body-height. The blood-volume was greatly reduced and it was also reduced when referred to unit body-weight, unit surface area and unit body-height. There was also a reduction in the total circulating haemoglobin, total circulating RBC and total circulating plasma protein which was confined to the albumin fraction.

All the above findings returned to normal on treatment in hospital and by observing the individual rates of improvement, the pattern of recovery has been reconstructed. This recovery process has been divided into three arbitrary stages. Stage I (0-4 weeks) is characterised by a rapid rise in plasma volume to normal and by a decrease in body-weight and haemoglobin concentration. Stage II (2-12 weeks) is notable for the rapid rise in blood-volume to normal and the rise in plasma volume to figures in excess of normal. In Stage III (8-16 weeks) normal figures were reached for each of the factors measured.

An important clinical point is that the haemoglobin concentration, and sometimes the plasma protein concentration often fell during Stage I. Although this was so, the increase in plasma and total circulating volume was so great that the total amount of circulating haemoglobin and plasma protein was increased. Therefore, it does not necessarily follow that, because the haemoglobin concentration or serum protein concentration falls during the initial stages of treatment, the patient is necessarily not making satisfactory progress.

THE EFFECT OF TRANSFUSION IN PROTEIN DEFICIENCY

When a plasma protein infusion was given to a patient with severe hypoproteinaemia only a small part of the infused protein was found in the circulation 24 hours later. The percentage of infused protein retained was related to the mean serum protein concentration and to the total circulating plasma protein.

When a blood transfusion was given to a patient suffering from extreme tropical macrocytic anaemia with apparently only slight evidence of protein deficiency, the haemoglobin of the infused blood remained in the circulation, but the plasma protein was no longer present 24 hours later and, in some cases, some of the plasma protein that was originally present in the circulation had also left it. On the other hand when a blood transfusion was given to an anaemic patient who was neither macrocytic nor hypoproteinaemic, both the haemoglobin and the plasma protein of the infused blood were retained in the circulation 24 hours later.

FRACTIONAL TEST MEAL INVESTIGATION

Of 21 POW patients, two had a histamine resistant achlorhydria, five had no free acid after a gruel meal but responded to histamine, one had hypochlorhydria, three had a delayed emptying time and ten were normal. After treatment in hospital all the patients produced free acid even without histamine ; one had hypochlorhydria, one had a delayed emptying time and the remaining nineteen were normal.

Nicotinic acid had no effect on the fractional test meal findings, but there was a marked improvement while the patients were receiving riboflavin. There was also an improvement in the few cases studied, while the patient was receiving liver extract.

After 3 transfusions of concentrated plasma

8 weeks later

1. Patient with gross anasarca, ariboflavinosis and parakeratosis—after three transfusions of concentrated plasma—eight weeks later.

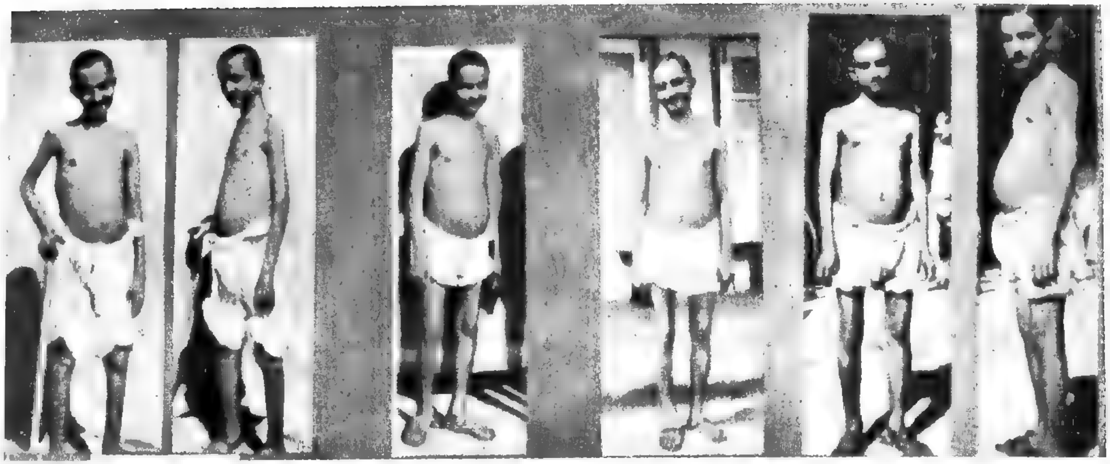
After 2 concentrated plasma and 2 blood transfusions

3 weeks later

6 weeks later

2. Patient with grave macrocytic anaemia and anasarca—after two concentrated plasma and two blood transfusions—three weeks later—six weeks later.

PLATE XIII



After 2 plasma transfusions — 3 weeks interval — 6 weeks interval

Patient with gross anasarca—liver enlarged and firm but regular—after two plasma transfusions—three weeks interval—six weeks interval.

TESTS OF ABSORPTION FROM THE GASTRO-INTESTINAL TRACT

In marked contrast to the observations made in the European prison camps of Belsen and Lamsdorf, diarrhoea and other signs of impaired absorption from the gastro-intestinal tract were rare in Indian prisoners by the time they had been repatriated to India. A few (less than 5 per cent. of those who were sufficiently ill to require hospital treatment) did, however, complain of diarrhoea. The following conclusions are based on a study of these patients only and are not, therefore, representative of all repatriated Indian prisoners. In such patients there was an impairment of the glucose tolerance test characterised by (a) a low fasting blood sugar concentration, (b) a low rise in blood sugar concentration after 50 g. glucose and (c) a positive difference between 3-hour blood sugar concentration and the fasting level. By the time the patients were fit for discharge from the hospital, the glucose tolerance test had returned to normal in all respects.

While the patients were receiving nicotinic acid, there was a slight improvement in the glucose tolerance curve as judged by the height of curve above the fasting level. Riboflavin, in the dosage used, had no effect. Nicotinic acid, together with liver extract, had a beneficial effect in all five cases tried.

In addition there was an impairment of the fat tolerance as judged by both the height and the time of the rise in serum total fat and the time of the rise of serum cholesterol. There was also a low fasting serum cholesterol, but no change in the fasting serum total fat. After treatment in hospital the fat tolerance returned to normal. Most patients with diarrhoea also had steatorrhoea which improved during treatment in hospital.

CHAPTER XVII

Neurology

MILITARY NEUROLOGY IN INDIA

ADMINISTRATION

Prior to April 1943, there was no separate consultant for neurological disorders. However, sanction for a consultant in neurology, and for a pool of four neurological specialists, additional to hospital establishment, was obtained in February 1943, and Brigadier D. McAlpine arrived in India from the Middle East in April 1943, to hold charge of the new office of consultant.

The consultant neurologist apart from being responsible for the treatment and disposal of officers and other ranks suffering from a variety of neurological disorders, was also actively concerned with problems relating to general medicine and hygiene. In the India Command he also collaborated with the consultant surgeon in the supervision of neurosurgical conditions, peripheral nerve injuries and paraplegic disorders, and the responsibility of supervising special centres for these fell chiefly on him. He also served as consultant to ALFSEA and in this capacity paid periodic visits to the mobile neurosurgical units.

In 1943, Nos. 2 and 3 Mobile Neurosurgical Units moved to the forward areas. Sanction was obtained for a neurosurgical centre (100 beds) with its own establishment (officer commanding, one neurologist, one captain IAMC or RAMC, two masseuses, one corporal WAC(I), stenographer). A scale of equipment was provided. The centre was opened in January 1944 at No. 126 IBGH(BT), Poona. All neurological cases in category E (unfit for further service) as well as cases sent in for investigation were admitted to this centre. In 1944, under this heading 137 officers and 603 BORs were admitted. In addition, a weekly out-patient clinic was held. IORs suffering from organic neurological conditions were admitted to No. 2 IBGH (IT), Kirkee. Early in 1944 a neuropathologist was posted to No. 126 IBGH. The neurological centre thus constituted proved to be of considerable value. He was also available for consultation by the other hospitals, and gave weekly clinical demonstrations which proved extremely popular with all medical officers in the area.

A scheme for grading medical officers in neurology after a course at the centre lasting three months was approved early in 1944, and in the second half of that year three officers, two IAMC and one RAMC, already graded in medicine, were also graded in neurology. The results of treatment of such conditions as acute poliomyelitis, polyneuritis and sciatica by a special staff of physiotherapists, working under the supervision of a neurologist, proved the value of the segregation of such cases in a neurological unit.

By the end of 1944, the direction of the flow of casualties across India had become ‘ east-west ’. The role of the hospitals in Poona

became chiefly that of transit centres before evacuation ex-Bombay. In order that it should be nearer the reception areas, the neurological centre was moved to Secunderabad [attached to No. 134 IBGH(BT)]. The centre remained in this location until it was disbanded early in 1946. Plans were approved for incorporating the neurological centre (together with neurosurgery and neuropathology) in a specialist hospital for Indian and British troops at Jalahali. But with the surrender of Japan this project was cancelled and No. 134 IBGH which originally admitted British patients was converted into a hospital for Indian troops. The neurological centre from No. 134 IBGH moved to No. 127 IBGH (BT), Secunderabad. Indian cases were then accommodated in the medical division of No. 134 IBGH (IT).

Early in 1944, a neurological specialist, was posted to Dacca. In addition to acting in a local consultative capacity, he took charge of the milder forms of head wounds evacuated by No. 3 Mobile Neurosurgical Unit at Comilla.

In April 1945, an adviser in neurology to the Eastern Command was sanctioned in order to provide for the growing consultative work along the northern route of evacuation. Major (acting Lieut.-Colonel) A. D. Leigh, RAMC, held this post until the arrival in June of Lieut.-Colonel A. Turner, RAMC. In September 1945, this officer succeeded Lieut.-Colonel H. Garland as adviser to the Southern Army, Lieut.-Colonel F. A. Elliott replacing him in the Eastern Command. The appointments of the advisers were abolished early in 1946.

In May 1945, Brigadier D. McAlpine returned to the United Kingdom, being relieved by Brigadier D. Denny Brown who remained until 30 November 1945 when, following the end of the war with Japan, and the return of the POW, the appointment was abolished.

CLINICAL NEUROLOGY

The chief neurological disorders occurring in base areas were meningococcal meningitis, acute poliomyelitis, epilepsy, peripheral neuritis, late effects of head injury and neurological complications of malaria and heat stroke.

Meningococcal Meningitis : In 1943, over 1,700 cases of this form of meningitis were reported, 800 of these occurring in the Central Command with a mortality rate of 18 per cent. This high figure was attributed largely to the failure of many IOR patients to report sick until a late stage of the disease. Publications of warnings in command orders, and the issue of a special technical instruction on the subject did much to bring down the mortality rate, a figure of 6·6 per cent. being reached in the Central Command during the first quarter of 1945. The renal difficulties accompanying the use of the less soluble sulphonamide drugs in the hot season were also a problem, which was finally solved by the introduction of sulphamezathine. A solution of this substance for intravenous use was made available in transfusion units from January 1945, and became available in all hospitals in August of that year[1].

[1] See also page 293.

Acute Poliomyelitis : During 1941, 12 cases were reported in the Army in India. In 1942, 42 cases (28 per cent. mortality); in 1943, 42 cases (31 per cent. mortality); in 1944, 96 cases (27 per cent. mortality) and in 1945, 186 cases (22 per cent. mortality) were notified. The Consultant Neurologist, (Brigadier D. McAlpine) issued a special report on the disease in February 1945, drawing attention to the increased incidence of the disease amongst British troops in India during the war, to the relatively high incidence in officers and officer cadets and to the high mortality and severe disability resulting from this condition[2].

In 1944, the high proportion of cases with respiratory failure created a heavy demand for mechanical respirators (iron lungs). Twenty-seven of these instruments were made in India (Rawalpindi Arsenal), six of them being sent to ALFSEA. In addition 29 iron lungs were generously loaned by various civil hospitals and medical colleges.

Diphtheritic Polyneuritis : In May 1943, cases of diphtheritic polyneuritis were reported in men undergoing jungle training, and in July 1944, men from the Special Force (3rd Indian Division) began to arrive in India from Burma with signs of polyneuritis. During the last six months of 1944, more than 200 cases of diphtheritic polyneuritis were received by the India Command. Many of these cases showed a striking similarity to those observed in the Middle East in the fact that there was often evidence of cutaneous infection, the jungle sore appearing as the counterpart of the desert sore of Middle East Force. In more than one-third of the cases there was a history of jungle sore, in another third of jungle sore plus sore throat, and in the remainder faucal or nasal inflammation alone. Few of the cases showed any evidence of cardiac damage, and in the neurological centre to which the majority of these cases were admitted, a policy of early rehabilitation was adopted, at first in bed and later in classes under a physical training instructor. This regime resulted in remarkably rapid recovery in all but the most severe cases. Uncomplicated cases of diphtheritic paralysis were not evacuated to the United Kingdom. Schick testing of jungle troops, with active immunisation of susceptibles was recommended, but the jungle fighting came largely to an end before the next monsoon season. Small outbreaks of jungle sores also continued to occur in jungle training in India, but subsided without leaving any considerable number of cases of polyneuritis[3].

Scrub Typhus : From November 1943, onwards, cases of scrub typhus occurred in Assam and Burma. A small percentage of these cases showed neurological complications such as stupor, mental confusion, convulsions, coma, and more rarely bulbar and neuritic sequelae. Studies of the treatment of comatose patients in this disease, and in cerebral malaria, meningococcal meningitis, head injury, etc., were made by Lieut.-Colonel G. A. Ransome IMS/IAMC (adviser in neurology, ALFSEA). An effective management of such patients in a propped up position with feeding by gastric tube was devised[4].

[2] See also page 286.
[3] See also page 300.
[4] See also page 533.

Arsenical Encephalopathy : A relatively high incidence of this complication of arsenical treatment occurred in Indian troops. An investigation was carried out by the consultant venereologist, the neuro-pathologist and others. The low average weight of the Indian soldier and his lack of toleration of intensive treatment were found to be the essential factors[5].

Heat Stroke : Forty deaths from this cause occurred in 1943, the majority of them being BORs. As a result of better education of those recently arrived from cooler climates, the incidence fell steeply in 1944 and 1945. The management of some cases of prolonged unconsciousness was a difficult problem. A few examples of cerebellar ataxia following prolonged hyperthermia were seen[6].

Epilepsy : Amongst British personnel cysticercosis proved to be a not uncommon cause of epilepsy. In 1943, Major J. MacGregor reported that of the 63 established cases of epilepsy (45 cases occurring in BORs and 18 in Indians or Anglo-Indians) cysticercosis was proved radiologically in 3 cases. Major A.D. Leigh reported that of 25 cases of epilepsy in IORs only one (a sweeper) showed cysticercosis. In 1944, of 53 BOR cases diagnosed as epilepsy five had palpable cysts, not evident radiologically. In 14 others the onset of fits one year or more after arrival in India raised the possibility of cysticercosis though no confirmatory evidence could be found.

Sciatica : This was a common cause of prolonged disability among British troops. Complete rest in bed for a period of three weeks usually resulted in relief but relapse was not uncommon. Relapsing cases were evacuated to the United Kingdom unless there were clear signs of prolapsed intervertebral disc, when surgical treatment was undertaken by the neurosurgical centre.

Brachial Neuritis : A troublesome form of brachial neuritis, commonly called ‘ infective neuritis ’ also led to considerable disability in some cases owing to the paralysis and wasting of shoulder muscles.

Deficiency Syndrome in POW : Following the recapture of Rangoon in May 1945, a number of released POW reached India. Instances of beri-beri neuritis were rare, but a number of cases presented difficulty in reading owing to retrobulbar neuritis. In a few (1 per cent.) loss of vision was severe, but complete blindness was not seen. A small number exhibited ataxia in addition, and a few had developed bilateral deafness. These conditions were previously known to occur in rare cases of severe pellagra, but in these repatriated prisoners few had signs of that disease, and such signs were particularly infrequent in the cases with neurological disorders. Following the surrender of Japan many more such cases were seen. Out of 3,667 sick ex-POW from the prison camps of Singapore, Malaya and Thailand subjected to a neurological survey, 110 cases were found to be suffering from beri-beri neuritis, 185 from partial loss of vision due to retrobulbar neuritis, 60 from spinal ataxia, 13 from deafness and 3 from laryngeal palsy. In addition, a

[5] See also page 79.
[6] See also page 171.

small group of eight BORs who had been in Changi Prison Camp, Singapore, exhibited a spastic paraplegia resembling lathyrism. Each of these disorders occurred independently in a few cases, but most of those affected by severe ataxia had also severe amblyopia[7].

Traumatic Paraplegia : The care of patients suffering from paralysis of the lower limbs (traumatic paraplegia) gave rise to much anxiety. The long and delayed evacuation led to the formation of deep bed sores from which recovery was slow and difficult. Such patients were admitted to four base hospitals where extra nursing staff and equipment was provided. The supply of special mattresses, spinal carriages, revolving beds, etc., was, however, extremely limited throughout the war. Such patients tolerated heat poorly, and the centres in Lucknow and Ranchi were abandoned. Even after the concentration of these in two centres (Secunderabad and Dehra Dun) in the summer of 1945, the supply of special equipment remained a problem. Bed sores and bladder infection in such cases are preventable, and continuous efforts were made to improve early care by insisting on suprapubic drainage of the bladder and regular movement of the patient. This insistence upon regular movement and nursing of the patient by a personal orderly throughout evacuation became possible only late in 1945.

ACUTE POLIOMYELITIS

During World War II cases of acute poliomyelitis occurred in various theatres of war in which British and Dominion troops served, notably Malta, North Africa, Italy and the Middle East. In India the disease did not appear amongst British troops until 1942.

According to the Annual Report on the Health of the Army in India only 10 cases in BORs were notified between 1938 and 1941. In 1941 only one case was reported. The following figures show the rise in incidence of the disease during the years 1942-45 inclusive.

TABLE I

Incidence of acute poliomyelitis—1942-45.*

Troops	1942 India plus Eastern Army		1943 India plus Fourteenth Army		1944 India Command		1945 upto November India Command	
	Actual number	Rate per 1,000	Actual number	Rate per 1,000	Actual number	Rate per 1,000	Actual number	Rate per 1,000
British officers	32	1·7	19	0·5	43	1·4	73	...
Officer cadets	...	...	...	...	9	12·7	13	...
BORs ...	38	0·3	23	0·1	42	0·3	70	...
QAIMNS	...	...	...	...	2	1·5	2	...
IORs ...	5	0·01	10	0·01	15	0·01	9	...
Total ...	75		52		111		167	

[7] See also Volume on *Prevention of Diseases, Malaria Control and Nutrition.*

*The figures for 1942-44 are taken from a report on acute poliomyelitis prepared by Brigadier D. McAlpine in 1945. Those for the years 1945 are taken from Brigadier D. Denny Brown's report on poliomyelitis in 1945.

With the exception of small outbreak of 25 cases at Ranchi in 1942, the disease did not appear in an epidemic form during these years.

The outstanding features of the disease during the last war were (i) the rise in its incidence in the Army in India from 1942 onwards, (ii) the fact that this rise took place only in British troops, (iii) the high incidence in British officers and officer cadets as compared with BORs (for each of the years mentioned, British officers were affected five times more frequently than BORs) and (iv) a high mortality rate and high incidence of severe residual paralysis.

	1942	1943	1944	1945
Number of cases ...	42	42	96	186
Deaths	12	13	26	42
Mortality rate per cent. ...	28	31	27	22

In 1944, out of 70 officers and other ranks who survived the disease, 47 were evacuated to the United Kingdom ; as far as could be ascertained only seven cases recovered sufficiently to permit of their return to duty in India.

Seasonal Incidence : The majority of the cases occurred between March and October. In 1944 and 1945 the peak months were July and August. The significance of this hot weather incidence will be discussed later.

Geographical Distribution : The disease occurred sporadically with a tendency to small focal outbreaks of 4-10 cases. These foci were usually related to cantonments and the proportional density of British troops. Accordingly the great majority of the cases occurred in the Central Command and Southern Army. In 1944 and 1945, there was an increase in the number of foci as compared with the previous two years. In 1945 AFA 35 in respect of notification of acute poliomyelitis was amended in order to include, *inter alia*, movements within 14 days prior to the onset of the disease. Such information as was available for the years 1942-45, suggested that the disease was prone to attack individuals who had been on a recent journey, especially when that individual was an officer. In 1945, 44 of a total of 186 cases [and 17 out of 21 Royal Air Force (RAF) cases] had been on extensive railway journeys in the two weeks preceding the onset of the disease.

Age and Length of Service: During 1944, only one case occurred over the age of 40 years and three cases between the ages of 30 and 40 years. The longest period of service in India was 3¼ years, and the shortest four weeks, while most cases had served less than two years. It appeared that the disease tended to occur in young men who had served in this theatre for a comparatively short time.

Previous Health : In an appreciable number of cases there was a history of ill health within a month of the onset of the disease, diarrhoea, coryza and malaria being the commonest complaints. A few cases followed closely after prophylactic inoculation. In 1944, 5 per cent. of British cases occurred among hospital patients who had been undergoing treatment for some other condition for a period exceeding two weeks; no other cases of poliomyelitis were under treatment in the hospitals concerned. These men were either carriers of the virus or became infected from some source in the hospital.

CLINICAL FEATURES

Prodromata : A variety of symptoms preceded the meningitic (preparalytic) stage of the disease by 1-10 days. Not uncommonly these symptoms passed off after one or two days, only to recur a few days later and be followed by signs of invasion of the nervous system. This biphasic tendency has been interpreted by Draper (1917), Macnamara (1935) and others as indicating a preliminary stage of systemic infection. Its frequency in service personnel lends support to this view. The following symptoms were met with—fever, chill, general malaise, headache, vomiting, anorexia, sore throat, coryza, diarrhoea, backache and vague body or limb pains 'like influenza'.

In the abortive form of the disease such symptoms may not be followed by meningitis or paralysis and owing to the fact that in a number of tropical diseases the initial symptoms may be similar, the correct diagnosis was seldom made. In the non-paralytic form, constitutional symptoms were followed by signs of meningitis and a pleocytosis in the cerebrospinal fluid. In 1945, 6 out of 13 cases reported from Mhow belonged to this group. Their recognition might have depended on the clinical acumen of the medical officers concerned.

Paralytic Forms of the Disease : As in the Middle East the disease tended to attack the lower dorsal and lumbar cord primarily or predominantly so that paralysis of the lower limbs with or without involvement of the trunk muscles, was the commonest form of the disease (approximately 50 per cent. of all cases). Retention of urine, usually of a temporary nature, was a common occurrence. In a small percentage of cases the upper limbs were principally affected. Severe residual paralyses were common. Fatal cases fell into two groups, (a) bulbar polio-encephalitis in which the majority of cases succumbed through respiratory or circulatory failure and (b) the ascending type in which paralysis of the lower limbs was followed by paralysis of the trunk and upper limbs, and lastly by bulbar paralysis. Finally, in a small proportion of cases the effects of the disease were so localised as to be easily overlooked or misinterpreted. Diplopia and/or nystagmus were occasionally seen as the only evidence of polio-encephalitis.

The clinical features of the disease were fully described in the Medical Directorate, GHQ, Technical Memorandum No. 46 issued in March 1945. Attention was drawn to the need of early diagnosis, "In the presence of headache and fever in a British soldier, a complaint of

backache with pain or weakness in a limb should suggest acute poliomyelitis and should be followed by lumbar puncture ".

Cerebrospinal Fluid : A typical pleocytosis and increase in protein content were the usual findings. In a small number of cases the fluid was normal in the acute phase of the disease.

Differential Diagnosis : The meningococcal and acute benign lymphocytic forms of meningitis were rare in British personnel in the India Command during the last war. Therefore, a cell increase particularly of lymphocytes, in the cerebrospinal fluid in a patient who presented signs of meningitis was usually due to the virus of poliomyelitis. Malaria was sometimes a complicating factor in diagnosis which could not be solved except by an examination of the cerebrospinal fluid. A reported outbreak of poliomyelitis among Indian troops in 1945 proved on investigation by the consultant neurologist to be due to mumps meningitis. The condition which caused real difficulty in diagnosis was acute toxic polyneuritis. It has already been pointed out that in IORs the increase of acute poliomyelitis was not very marked. On the other hand, acute toxic polyneuritis was commoner in them than in British troops. Constitutional symptoms were followed by paraesthesiae and a four limb flaccid paralysis with varying degrees of sensory loss ; in addition a unilateral or bilateral facial palsy was sometimes met with. Signs progressed for some days and reached the stage of complete quadriplegia with respiratory paralysis and retention of urine. The findings in the cerebrospinal fluid were important since characteristically the protein was increased causing a yellowish tinge in the fluid. Even in severe cases, provided the stage of respiratory paralysis was overcome, the prognosis was good, unlike a correspondingly severe case of acute poliomyelitis. The symmetry of the paralysis, the sensory loss and the changes in the cerebrospinal fluid were helpful points in differential diagnosis.

Treatment : The general principles to be adopted in the treatment of acute poliomyelitis were fully described in the technical memorandum already referred to ; they included (i) rest in bed as soon as the disease is suspected, (ii) a high standard of nursing, (iii) relief of pain by packs or heated cradle, and by analgesics, (iv) the prevention of stretching of paralysed muscles by means of correct posture and (v) physiotherapy.

EPIDEMIOLOGY

During the present century much thought has been given to the problem of acute poliomyelitis by epidemiologists in the USA, the Scandinavian countries and in Australia, but as yet there is no uniform opinion as to the mode of spread of this disease. It is known that the virus can be isolated from the stools of recent paralytic cases, of abortive cases, and of close contacts. It may be present in sewage and in a variety of non-biting fly in the infected areas. The virus is present on the posterior wall of the pharynx and peritonsillar region during the

acute stage. The bulbar form of polio-encephalitis may follow tonsillectomy. These facts suggest that the usual portals of entry for the virus are the tonsil, pharynx and intestine (McAlpine, 1945).

The incidence of acute poliomyelitis in British troops serving during the war in India was considerably greater than in the Army in the United Kingdom. A similar susceptibility was noted in American troops who served in India. From 1942 onwards, the Army in India had been reinforced by the arrival of fresh troops from the United Kingdom and it was in these troops that the disease occurred. Acute poliomyelitis was rare among IORs and there was no rise in the incidence of the disease among them during the recent war, or as far as was known, among the Indian population as a whole. Similarly in the other theatres already mentioned, poliomyelitis was rare among the adult population. In the Malta epidemic the adult native population virtually escaped, while the mortality among the children was much lower than in the service personnel. These facts suggested that the civilian population in these countries inherited or acquired a large degree of immunity to local strains of the virus during childhood, whereas British and American troops were exposed to strains which differed from those in their home countries and to which they were not immune (McAlpine, 1945).

In view of its relative frequency, the part played by previous ill health in precipitating an attack of poliomyelitis must be briefly considered. It may be assumed that an attack of malaria acted indirectly in lowering resistance to infection ; on the other hand, dysentery may have borne a special relationship in view of the probability that the intestine is one of the portals of entry for the virus. Acute poliomyelitis among British troops in India was mainly a disease of the hot weather months, thus coinciding with the season of flies and dysentery; this fact suggested that there might have existed one or more factors common to the epidemiology of these two conditions (McAlpine, 1945).

The explanation of the striking fact that the disease was five times more common among British officers than among other ranks in India appeared to provide the key to the problem of transmission. It was assumed that officers and men started on the same mark of susceptibility to infections of all kinds when they arrived in India. In what way then did the life of an officer in India differ from that of the other ranks so as to increase his chances of contracting this disease ? His personal habits and living conditions did not appear to offer an answer to this question. The emphasis on the alimentary tract in poliomyelitis suggested that attention should be focussed on a comparison of the conditions under which officers and other ranks were fed (McAlpine, 1945). With the co-operation of the DDH and P and the QMG's Branch, an analysis was made of the difference in feeding conditions of British officers and other ranks. The following is a summary of this investigation taken from a report on acute poliomyelitis in the India Command.

(i) *Messes :* Officers' messes were generally catered for by contractors and, therefore, supervision of kitchens was seldom effective.

When an officers' mess was staffed by the army personnel the cook although he may have been instructed in kitchen hygiene, in the absence of proper supervision would revert to unhygienic methods. Foodstuffs for officers' messes were often purchased from the local bazaars. Uncooked or cold food was frequently eaten, and lastly, communal eating utensils were used which, owing to lack of boiling water for washing-up purposes, were seldom hygienically clean.

Messes of BORs were staffed by Indian personnel who were subject to inspection by the orderly officer, the medical officer, the hygiene officer and the specialist catering officer. In the case of officers' messes such inspections, under war conditions, were irregular and often perfunctory. Other ranks were supplied with rations according to the RIASC specification. Cold dishes were seldom served with the exception of tinned products. Each man used his own mess tin and other eating utensils, and as a rule washing-up conditions were much better than in the officers' messes.

(ii) *Travelling :* Officers used restaurants on trains and in stations extensively since they seldom carried rations, whereas with the exception of sergeants, men relied on rations carried with them. Few transit camps had a reputation for cleanliness ; adverse conditions would be shared equally by officers and other ranks.

(iii) *Off-duty Hours and on Leave :* Both officers and other ranks were exposed to infection by visits to the civilian establishments, but the risk was greater in the case of officers because as a rule they ate away from their messes to a greater extent than the other ranks ; hotels and clubs were mainly or exclusively used by them ; and the officer class tended to eat more cold or uncooked dishes than the other ranks.

An example of the way in which officers were exposed to a source of infection which was not open to the other ranks was the case of an outbreak in the Seagreen Hotel, Bombay. Eight officers who either were staying or had stayed in this hotel during the second half of October 1944, developed acute poliomyelitis between 26 and 29 October. Five of these officers were taken ill within three days of leaving the hotel ; four officers died. A naval officer was taken ill on 7 November and died three days later. The proprietor's daughter died of the disease on 24 November after three days illness.

Thirty-two young officers arrived on leave at the hotel on 15 and 16 October from the same training unit. Two of them contracted poliomyelitis after suffering from diarrhoea for several days. At a later date 24 of the remainder answered a questionnaire regarding their health during their stay in the hotel. All were fit on arrival. After three or four days, eight of them felt ill with headache ; four of them had diarrhoea and a sore throat and two of them had, in addition, fever and pain in one leg. The symptoms were severe enough to confine several of them to bed for two to three days.

The distribution of the cases among personnel occupying different rooms in widely separated parts of the hotel (except in one instance), the

onset of symptoms in eight cases within a period of three days, and the history of diarrhoea among several of the officers staying in the hotel at the time, suggested that the kitchen was the probable source of infection. The possibility that the proprietor's daughter was infected from fomites was suggested by the fact that she was not in contact with other cases and that she contracted the disease 11 days after handling the bed clothes removed from the room of the naval officer who died on 10 November.

PREVENTION

The occurrence of the disease during the hot weather months, the conclusions reached as to the significance of the higher officer rate, and the part played by a recent journey in precipitating the disease in many cases pointed to the contamination of food and eating utensils as an important factor in the spread of the disease in the India Command during the war.

In the report on acute poliomyelitis in the India Command already referred to, a number of recommendations were made with a view to reducing the risk of the disease ; these may be briefly summarised as follows :—

(i) An improved standard of hygiene in all messes, elimination of contractors from messes, employment of British cooks wherever possible, and improved washing-up facilities.

(ii) A further warning to British troops of the risk which they run by the consumption during the fly season of certain articles of uncooked food.

(iii) The introduction of modern methods of kitchen hygiene in all civilian controlled establishments, including railway restaurants, and a closer supervision of their kitchens by army medical officers.

During the hot weather of 1945, a successful fly prevention campaign was carried out in Assam, Burma and Bengal with a view to reducing dysenteric diseases. Nevertheless, the proportion of fresh cases of poliomyelitis from or in transit through Assam and Bengal in that year was approximately twice as great as the year before. Faecal contamination of water supplies was suspected. As the local reservoir of the disease was unknown, it was proposed to boil all drinking water in the event of a large outbreak, but fortunately this did not become necessary.

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MENINGOCOCCAL MENINGITIS

The conditions necessary for the appearance of meningococcal infection in a community are fulfilled by war. A rising carrier rate amongst a large body of recruits living in overcrowded quarters will, in the event of unfavourable climatic conditions, result in the outbreak of meningitis. Such conditions were present during World War I in certain parts of Britain.

In the India Command during the last war vast numbers of men were recruited both for the army and labour battalions. The physical condition of these men on enrolment was often poor. Accommodation in the camps was in some instances inadequate and as a result overcrowding was relatively common. On the other hand, the disease was rare throughout the war amongst British personnel, doubtless due to the better conditions in which they lived. The highest incidence of meningitis occurred during the cold weather months, October to March, contrasting with the low incidence of acute poliomyelitis during the same period.

Between 1 January and 30 November 1943, approximately 1,700 cases were notified among IORs and the personnel of labour battalions. The mortality rate was 18 per cent. despite the use of sulphapyridine. Of this number 800 occurred in the Central Command. The consultant physician to that command, Brigadier B. Schlesinger, drew attention to the relatively high mortality rate and to its causes. These were included in the Medical Directorate, GHQ, Technical Instruction No. 53, and are amplified in the following paragraphs.

(i) Failure on the part of the patient to report sick until the disease was well established. Certain labour camps housed 15,000 to 20,000 men. On an average two medical officers were responsible for the medical care of this large body of men. Not uncommonly, through ignorance or neglect, men overtaken by fever lay down in their tents without reporting sick; consequently, if the case was one of meningococcal meningitis there was a delay of 24 to 48 hours before he reached the hospital.

(ii) A delay in diagnosis, especially during the malarial season. An attack of malaria not infrequently cloaked the symptoms of under-lying meningitis.

(iii) Failure to maintain an adequate concentration of the sulpha drugs through faulty administration. In 1942 and 1943, insufficient attention was paid by the medical officers to the necessity of maintaining an adequate concentration of sulphapyridine in the blood by means of adequate and regular dosage throughout the 24 hours.

(iv) A state of malnutrition in those who contracted the disease.

As already stated, the physical condition of many of the recruits who contracted meningitis was poor, and their chance of survival was thereby lessened.

DIAGNOSIS

Meningococcal infection is primarily septicaemia, meningococcal meningitis being a common but not constant complication. In the Indian patient the recognition of the septicaemic stage of the disease is difficult, nor can reliance be placed on the characteristic petechiae which might be absent or easily missed. In IORs headache, a chill, fever, general malaise and vomiting, particularly when occurring between October and March, should suggest the diagnosis of meningococcal meningitis. These symptoms may last a few hours or days, and in the absence of treatment, are followed by an increase in the intensity of the headache, pain referred to the back of the neck, drowsiness and coma. Neck rigidity is an important diagnostic sign but it may only appear in the later stages of the disease ; therefore its presence should not be regarded as essential for the diagnosis of meningitis.

The cerebrospinal fluid pressure is raised. The fluid is opalescent or turbid with a polymorphonuclear count varying from a hundred to several thousand cells. The gram negative diplococcus is present on smear or culture in most cases.

The acute septicaemic form of the disease is comparatively rare. It begins abruptly with headache, shivering, fever and vomiting. Within a few hours haemorrhages occur into the skin, mucous membranes and sometimes suprarenals, causing a low blood-pressure and signs of collapse. Abdominal pain may be a feature. There may be no clouding of consciousness. Recovery is rare. The abrupt appearance of mental confusion or a hypomaniacal state with headache and fever in a previously healthy individual should suggest an acute meningo-encephalitis. Coma ensues and is sometimes accompanied by epileptiform fits or a hemiplegia. The cerebrospinal fluid may be normal. Despite treatment death usually occurs in 6-36 hours.

A chronic meningococcal septicaemia is characterised by intermittent fever, skin lesions and joint pains. A persistent leucocytosis and the therapeutic effects of chemotherapy are helpful points in the diagnosis.

The differential diagnosis from malaria may be difficult although the seasonal incidence of the two diseases is not the same. The finding of malarial parasites in a patient who complains of severe headache and fever must always be followed by lumbar puncture.

TREATMENT

Successful treatment of the pyogenic forms of meningitis depends on early diagnosis, prompt chemotherapy and skilled nursing. Medical officers and personnel of medical inspection rooms of Indian units were advised to send to hospital any men who, especially during the winter months, reported sick with headache and fever. On admission into the hospital it was recommended that lumbar puncture should be carried out without delay in suspected cases of meningitis ; if the fluid was turbid chemotherapy should be started at once, with the following doses.

(a) Ordinary case—The first dose should be given intravenously, the contents of one ampoule of Dagenan soluble (1 g.) should be diluted in 10 c.c. or 20 c.c. of saline and should be injected slowly into a vein. Subsequently the drug should be given by the mouth at intervals throughout the 24 hours, first day 16 tablets (8 g.), second day 12 tablets (6 g.) at 4-hourly intervals, third day 8 tablets (4 g.) at 6-hourly intervals, and fourth to seventh day 6 tablets (3 g.) at 8-hourly intervals. (b) Severe case—A solution of sulphamezathine became available in the India Command in 1944, and its use by intravenous route was advised in severe cases. The initial dose was 6 g. and the second to fourth doses 3 g. at intervals of 6 hours. Thereafter, sulphamezathine in tablet form (each tablet ½ g.) was recommended at the rate of 4 tablets for two days and followed by 2 tablets for two days, given 6-hourly.

In addition to these measures, emphasis was laid on the necessity for skilled nursing and for an adequate amount of fluid nourishment. The use of an intragastric Ryle's tube, was advised for comatose patients.

Results of treatment : From 1943 onwards, there was a definite fall, both in the incidence of the disease and in the mortality rate. The following figures relate to the Central Command :—

Year	Admissions	Deaths	Mortality rate (per cent.)
1943	863	113	13
1944	418	42	10
1945 (first quarter) ...	106	7	6·6

The fall in the incidence of meningitis in the India Command as the war progressed was due to improved living conditions in the training units and labour corps centres. The improvement in the mortality rate can be attributed to the reduction in the time-lag between the onset of symptoms and the admission of the patient to hospital, and to the improved standards of treatment. It became apparent that intravenous sulphamezathine was the drug of choice in the treatment of severe cases. The mortality rate of 6 per cent. obtaining in the Central Command in the early part of 1945 compared very favourably with the low figure of 2 per cent. reached in the Army in England, and reflected great credit on the consultant physician and the medical officers and nursing sisters in that command.

NEUROLOGICAL SYNDROMES IN REPATRIATED POW FROM BURMA, THAILAND AND MALAYA

With the recapture of Rangoon in May 1945, a group of POW who had been confined in Rangoon by the Japanese since 1942, were released and sent to Calcutta. Those who were not in good pyhsical health were distributed to various military base hospitals for examination and

treatment. A group of 235 British sick, out of a total of some 650 British prisoners was examined by various consultant specialists in the hospital in Secunderabad, where they were under treatment prior to evacuation to the United Kingdom via Bombay. The findings in this group were typical of other smaller groups examined in other hospitals. In this group the majority of cases were suffering from chronic malaria, chronic dysentery and helminth infection. Oedema of the ankles without neurological signs was common. Only one severe case of nutritional oedema was seen, but there were several instances of recovering beri-beri, one moderately severe. The proportion of cases suffering from residual effects of beri-beri was, however, very small. Twenty-three of the patients complained of loss of vision for reading. After eliminating those who had lost spectacles or had developed errors in refraction, there remained fourteen who were suffering from a central scotoma. Nine of these had pallor of the temporal sides of the optic discs. Six of these had mild corneoscleral vascularity and other mild evidence of ariboflavinosis, but not sufficient to account for the impairment of vision. Two of these patients had slight residual neuritic beri-beri (weakness in dorsiflexion of the feet, wasting of the legs and absence of ankle jerks). Three others had a remarkable ataxia in gait, with loss of sensation of position in the feet, gross loss of vibration sense in the lower limbs, but no muscular wasting or weakness. One of these had in addition a severe bilateral nerve deafness. This retrobulbar neuritis had developed between eight and fifteen months after confinement in Rangoon jail. Ataxia had developed at the height of the visual disorder.

Since the visual and ataxic disorders were extremely unusual, the most severe cases were referred to the army neurological centre for close investigation. The presence of a syndrome corresponding to damage to the optic nerves and the dorsal columns of the spinal cord was confirmed (Garland, 1946). Lumbar puncture, blood count and X-rays of spine and optic foramina revealed no abnormality. The history of the conditions and its symmetry excluded such conditions as neuropticomyelitis, multiple sclerosis, or any of the commoner nervous diseases. It was soon appreciated that these disorders were identical with those reported by Landor and Pallister (1935) as occurring in civil jail prisoners in Singapore and Johore, and considered by them to be a nutritional deficiency disease other than beri-beri. A group of POW in the Middle East, suffering from the same disorders, was reported by Spillane and Scott (1945) and Spillane (1946) and was considered to result from dietary restriction.

The diet in Rangoon jail had been of parboiled rice with two or three small pieces of meat a week in a daily vegetable 'green stew' containing also the grains *dal* and gram. In the last two years of confinement one or two eggs a month had been added. In the last three months of confinement the food had increased in quantity. Records of exact quantities in the diet were not available. These patients were treated with injections of liver extract and this was recommended for the few similar cases seen in Indian troops who had been transferred to base hospitals in Dinapore, Lucknow and Dehra Dun.

Following the capitulation of the Japanese in August 1945, immediate relief was sent to the POW in Thailand and Malaya, and all except the most severely disabled were evacuated to India. On arrival in India the sick patients were hospitalised in base hospitals in Dinapore, Ranchi and Bangalore (Jalahali). Directives were issued drawing attention to the conditions 'nutritional retrobulbar neuritis' and 'nutritional ataxia'. Following the earlier experience of Landor and Pallister (1935), who had found thiamin ineffective in treatment, and yeast concentrates of slight value, intramuscular liver extract was generally recommended. The total number of sick POW received was 3,667, out of an estimated total number of about 60,000. Of those sick European and Indian troops repatriated to India the numbers found to be suffering from neurological disability are shown in Table I.

TABLE I

Residual neurological disability in patients from South East Asia received in India, August-September 1945 (*Denny Brown*, 1947).

Diseases	Indian	European	Total
Total patients received ...	1,597	2,070	3,667
Peripheral neuritis	42	68	110
Retrobulbar neuritis	129	56	185
Spinal ataxia	21	39	60
Deafness	10	3	13
Laryngeal palsy	2	1	3
Spastic paraplegia	9	0	9

The figures given for retrobulbar neuritis include those for ataxia, deafness, laryngeal palsy and spasticity except for four cases of ataxia, three of deafness, one of laryngeal palsy. The total number of cases of clear-cut neurological disorders (excluding mild and recovered states and conditions of doubtful aetiology) was 303 cases.

These conditions represent only the persistent chronic residual disability of the large number of cases of acute and chronic neurological disease which occurred during the years of confinement. For accounts of the problems presented in the POW camps, the reader is referred to the first hand accounts of Burgess (1946), Hazelton, (1946), Cruickshank (1946), Graves (1947), and others.

The residual disability was of special interest to the India Command in view of the necessity for providing the best treatment at the earliest possible date after release. The relief expeditions had been provided with special nutriments and large amounts of thiamin in view of the expectation of finding large widespread malnutrition. As a result all the cases returned through India had received these for 1-3 weeks before they arrived. The most extreme examples of beri-beri and famine oedema were suffering from co-existent unrelated diseases such as malaria

tuberculosis, or anaemia (Walters, Rossiter and Lehmann, 1947). Fresh cases of neurological disorders had not occurred in three months preceding release, owing to the greatly improved diet in this period. Considerable interest, therefore, centred upon the cases of nutritional amblyopia, ataxia and spasticity, because these were conditions of unknown aetiology and most of the men were not improving.

Amblyopia due to retrobulbar neuritis had been found in nutritional surveys in tropical countries for many years. It had been described by Stannus (1911-12) in South Africa, by Scott (1918) in Jamaica, by Nicholls (1935) in Colombo, by Moore (1937) in Africa, by Landor and Pallister (1935) in Malaya and by Metivier (1941) in Trinidad. It was well known to the Japanese who attributed it to beri-beri (Kagawa, 1938), and Elliot (1920) so referred to it in his book on *Tropical Ophthalmology*. The opinions of these and others are reviewed by Metivier (1941) and by Denny Brown (1947).

Nutritional ataxia was also well known and had usually been found in association with nutritional amblyopia (Moore, 1937). Usually a few of the most severely amblyopic patients exhibited ataxia, but in some groups of patients ataxia was the common disorder and a few of these cases presented amblyopia (Landor and Pallister, 1935 ; Scott, 1918 ; Metivier, 1941).

Spasticity resulting from nutritional disease had been rarely reported except in the disease lathyrism, where there is dispute as to whether the disorder results from consumption of a toxic substance in *Lathyrus sativa* (or according to some, in *Vicia sativa*), or whether a diet more exclusively of these results in an unbalancing effect comparable to the relationship of maize to pellagra. The historical aspects of these subjects are summarised by Denny Brown (1947).

In the POW, the retrobulbar neuritis was uniformly of the same type. The failure of central vision had been relatively rapid in the course of one to seven days, and usually without prodromal warning. In a few patients the eyes had smarted, watered or burned in the first few days, but most commonly the only sensation had been a dimness of vision and loss of ability to read, or to recognise friends. The periphery of the visual field remained intact. The central defect then had remained stationary for weeks or months, either with complete recovery or with residual mild defect. Relapse had been uncommon. No cases of complete blindness were known. The first cases of the disorder had occurred in September and October 1941, with sporadic crops of fresh cases, most numerous in Changi camp in Singapore in January 1942, and again in October-December 1943, (Burgess, 1946). Similar cases had occurred in Hong Kong (Wilkinson, 1944; Clarke and Sneddon, 1946) and the Middle East (Spillane and Scott, 1945). The residual condition seen on the return of the patients to India showed a central scotoma, either in the form of a large circular area extending out to 10° from the fixation point or a group of small island defects around the fixation point (Shapland, 1946 ; Hobbs and Forbes, 1946 ; Denny Brown, 1947), or variations between these extremes. The optic disc was uniformly pale when visual acuity was greatly reduced, and exhibited slight

temporal pallor or no significant change in the mildest cases. Papillitis had been observed by medical officers of prison camps in the acute stage. The retina showed no changes. The papillary reactions were preserved.

Nutritional ataxia was seen as an unsteadiness in gait which in slighter forms amounted only to a faltering in turning quickly, and in a few severe cases caused a gross irregularity in placing the feet and instability of posture. It was related to a loss of sense of position in the lower limbs, associated with a correspondingly greater loss of vibration sense, extending in some as high as the costal margin. The arms were not affected. In many the ankle jerks were absent and in some the knee jerk was unobtainable, but in some severe cases the knee and ankle jerks were present and even brisk. In a few cases the plantar responses were extensor and spasticity was present as well as ataxia. The patients usually gave a history of the gradual onset of the ataxia at the height of an attack of retrobulbar neuritis, but in four cases there had been no retrobulbar neuritis. A few cases of severe ataxia also suffered from a bilateral deafness or laryngeal paralysis. One patient was found with an amyotrophic muscular wasting and fibrillation with aphonia. The statistics of onset of ataxia were not recorded by the medical officers with the POW, for it was attributed to beri-beri, which was very common at the time. Denny Brown (1947) has submitted evidence that it forms a syndrome separate from beri-beri and resembling subacute combined degeneration of the spinal cord.

The most severe spastic cases formed a special group remaining from an outbreak of an encephalopathic illness in Singapore which has been described by Graves (1947). The final state was indistinguishable from lathyrism, though no consumption of lathyrus pea was known. It is considered likely that some special abnormality of diet had led to a similar metabolic disorder. The original illness had presented clinical differences from Wernicke's encephalopathy, and the residual disorder differed completely.

Although previous writers had attributed these disorders to deficiency in riboflavin there was little other evidence of ariboflavinosis in the returned POW. Administration of riboflavin had not relieved these conditions, even when given immediately after their onset. Nicotinic acid also failed to bring amelioration. Some medical officers of prison camps were convinced that the addition of fresh eggs to the diet could induce significant improvement in vision and gait if given soon after the onset of the disorder. Though retrobulbar neuritis and ataxia have long been known as occasional epiphenomena of pellagra, the cutaneous and mental features of this disease had been relatively rare in POW. It appears that the lack of some unknown factor in the vitamin B complex had occurred, and a general deficiency in fresh vegetables was considered the most important single causative dietary factor. The scientific importance of these disorders was related to their occurrence at a time when deficiency in protein (amino acids) was becoming recognised. For the first time a series of neurological deficiency symptoms separate from beri-beri was clearly established.

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POLYNEURITIS

Under this title are grouped post-diphtheritic polyneuritis, acute infective polyneuritis, the 'shoulder girdle syndrome' and neuritic beri-beri, examples of all of which occurred not infrequently among units of the Indian Army operating both at home, in Burma and in the Middle East.

POST-DIPHTHERITIC POLYNEURITIS[1]

Polyneuritis complicating faucal diphtheria rarely occurred since this disease is unusual in Indians and in British personnel the few sporadic cases were usually recognised early and received adequate amounts of antitoxin. It was demonstrated, however, in the Western Desert that delay in the administration of antiserum was a far more important factor in the aetiology of polyneuritis than any other factor. It was not prevented by the use of an initial dose even within 48 hours of onset if this dose was too small in relation to the amount of membrane present.

Polyneuritis as a sequel to desert or jungle sores, on which a virulent diphtheritic infection had been implanted, was a far more common condition. Sporadic cases were encountered in Iraq and the Middle East, and an epidemic occurred among the Chindit troops on their return from the jungles of Central Burma in 1944. Twenty-one such cases were reported from one CGH at Dehra Dun, (Ward and

[1] Incidence of neuritis in 365 cases of diphtheria with extrafaucal lesions among the POW in Singapore Island in 1942 and 1943 has been reviewed by Riddell (1950).

Mason, 1944), 78 more were diagnosed in the hospitals in the Southern Command in September and October 1944, while it was computed that the total number of men evacuated to India with this condition during the second half of 1944 exceeded 200.

An analysis of 101 examples of post-diphtheritic polyneuritis under treatment at a special neurological centre illustrates the relative frequency of the two sites of antecedent infection. (Garland, 1945).

	Cases
History of faucal diphtheria without cutaneous lesions ...	17
History of jungle sore without sore throat...	45
History of jungle sore with sore throat	39
Total	101

Of these 101 cases, only 23 had received anti-diphtheritic serum during their initial illness.

Polyneuritis occurs as a late sequel to cutaneous diphtheria ; in many cases the initial symptoms did not develop until three months after the healing of the infected skin lesions, and in the Dehra Dun series the average latent period was two months from the onset of ulceration but varied from four to seventeen weeks. It is probable that, during this period, toxin is slowly accumulating from a cryptic focus of infection in the sinuses or naso-pharynx.

Cutaneous diphtheria, whether implanted on a 'desert' or a 'jungle' sore, presented a fairly characteristic appearance. The lesions were usually situated on the elbows and fore-arms or on the knees and lower part of legs. A clearly defined, punched out ulcer would show a yellowish sloughing base, from beneath which oozed a thin greyish exudate. The margins of a typical ulcer were purplish and unhealthy in appearance, there was little surrounding inflammation and the lesion in general seemed indolent. The lesions were characteristically lacking in pain, and in many cases a surrounding zone of hypo-asthaesia could be demonstrated.

The onset of polyneuritis was not dramatic in many cases. Paraesthesia of the extremities preceded visual disturbance and weakness ; in others a blurring of near vision from weakness of accommodation was the earliest complaint, while in a few men nothing abnormal was noticed until their gait became ataxic, and difficulty was experienced in rising from a chair.

The developed case usually showed a symmetrical polyneuritis, though in a few cases a single limb might be more severely affected : in such cases there was no selective involvement of a limb which was or had been the site of ulceration. The area of objective sensory loss was much smaller than that of paraesthesia and was always peripheral in distribution. An important diagnostic feature of diphtheritic neuritis was the marked degree of impairment of postural and joint sensation which was constantly present, and not infrequently caused ataxia before muscle weakness became evident.

Loss of power is most evident in the extensor groups of muscles at the periphery of the limbs, resulting in foot and wrist drop with weakness of the intrinsic muscles of the hands. In most cases, however, disability was attributable far more to ataxia than to actual loss of motor power.

The tendon reflexes were lost at an early stage in the affected limbs, and their return was long delayed.

Palatal paresis had not been observed in polyneuritis following cutaneous diphtheria, and evidence of myocardial damage was rarely, if ever, found.

Early paresis of accommodation led to blurring of vision while reading, but even in those patients whose eyesight was more severely affected it was difficult to appreciate any depression of pupillary activity. Treatment comprised the injection of massive doses of antitoxin and prolonged physiotherapy. Recovery though slow was invariably complete within six months ; no case required evacuation from India and all were able eventually to return to full duty.

Cutaneous diphtheria is not a new entity in India, examples having occurred frequently in the past among troops operating on the North West Frontier, and among these polyneuritis had ensued from time to time.

ACUTE INFECTIVE POLYNEURITIS

Acute infective polyneuritis, a disease attributed to infection with a specific virus, was of more frequent occurrence among Indian troops than was acute anterior poliomyelitis. It appeared sporadically, gave rise to a prolonged period of disability and in rare cases ended in death from respiratory paralysis.

Its onset might follow an infection such as malaria or dysentery, but many cases arose spontaneously. The prodromal fever was more mild and prolonged than that of acute anterior poliomyelitis, while symptoms in the pre-paralytic phase were limited to paraesthesia of the limbs ; headache, meningeal irritation and severe pains in the back, characteristic of poliomyelitis, did not occur.

After a prodromal period varying in duration from four to ten days, the onset of polyneuritis was heralded by symmetrical peripheral anaesthesia which was itself followed within forty-eight hours by muscular weakness. This weakness rarely remained confined to the peripheral groups of the limbs, more commonly it showed a rapid centripetal spread resulting in severe flaccid quadriplegia. In such cases paralysis of the musculature of the chest will not rarely occur and might lead to embarrassment of respiration necessitating treatment in an iron lung. Cranial nerve lesions often developed concurrently with the peripheral nerve defects ; the facial nerve, often on both sides, being most commonly affected, while other of the lower cranial nerves were also frequently involved. The clinical findings might then simulate a post-diphtheritic paralysis.

Disturbance of sphincter action was very rarely found, even in the early invasive stage of the disease. Lumber puncture in such cases confirmed the diagnosis by revealing the greatly raised protein concentration without pleocytosis, originally described by Guillian and Barre.

Pathological changes have been found in both somatic and vegetative nervous systems, and in organs remote from the nervous system as well.

Changes in nerve structures comprise oedema with cellular infiltration of ganglia, trunks and roots, chromatolysis of ganglion cells, hypertrophy of the sheath of Schwann, and demyelinisation. In addition, a diffuse myocarditis, degeneration of cells of the liver parenchyma and of the suprarenal cortex have also been found.

The prognosis is not invariably good ; though no relevant statistics were available in India, as mortality varying from 14 per cent. to 40 per cent. has been reported elsewhere (Annotation *Brit. med. J.*, 1943). Indian patients treated made slow progress which was often incomplete at the end of six months.

Little is known of the natural history of this serious disease, and its further study in a country such as India, where it frequently occurs, should prove of value.

SHOULDER GIRDLE SYNDROME

The shoulder girdle syndrome is a condition bearing many pseudonyms and an obscure aetiology. It is characterised by severe pain followed by loss of power in one or more muscles of the shoulder girdle, without general systemic disturbance. Malcolmson (1836) gives a description of this affection which was then prevalent in India, and had been troublesome in the First Burma War, under the name ' a stroke of the landwind '.

The disorder was encountered occasionally in civil practice before the war, but became widely recognised among the Allied forces from 1941 onwards. Reference will be made to a series of 136 cases seen in army units in England and India between 1941 and 1945, and described under the title of neuralgic amyotrophy. At first it was thought that the lesion arose as a result of pressure exerted on the shoulder by the straps of webbing equipment, but further experience showed that this association was by no means constant. In a proportion of cases, a dissociated increase in the protein content of the cerebrospinal fluid indicated these to be examples of acute infective polyneuritis localised to the brachial flexus (McAlpine, 1944). A further small group followed the injection of serum or a vaccine ; such cases, after a latent interval of 7 to 12 days developed paresis of muscles supplied by the fifth and sixth cervical roots. Although not every patient showed a generalised reaction from sensitisation, the lesion was attributed to local oedema at the intervertebral formamina or in the nerve sheath. A typical example was seen in a British officer in Iraq, in whom a bilateral lesion

of the fifth and sixth cervical roots appeared on the eleventh day after the injection of two ampoules of anti-venene.

In the majority of patients, however, no history of pressure, or injection of foreign protein can be elicited and a normal cerebrospinal fluid excludes the diagnosis of infective polyneuritis. Although in a series of 136 cases trauma or antecedent illness was held to have precipitated the condition in 98, Parsonage and Turner (1948) concluded that the primary causal agent was a virus. The common habit of sleeping with the upper half of the body uncovered exposed the troops to nocturnal chill and this was viewed by some as an important precipitating factor.

Pain in the shoulder is a usual presenting symptom ; it is often intense, sometimes it radiates down the back of the arm and usually necessitates the use of sedatives at night. The painful initial phase which may last from a few hours up to a fortnight is followed by the development of flaccid paralysis of muscles of the shoulder girdle or upper arm. The muscles involved include serratus magnus, trapezius (lower fibres), spinalis, rhomboideus, sternomastoid, deltoid, triceps, biceps and brachialis, roughly in this order of frequency. The paralysis may appear on one or both sides, it may remain limited to a single muscle, usually the serratus magnus. Paralysis is often complete, the affected muscles showing full reaction of degeneration. The activity of tendon reflexes is impaired when the upper arm muscle groups are involved.

Paralysis is usually accompanied by a small zone of anaesthesia, often limited to the area of sensory supply of the axillary (circumflex) nerve, but occasionally extending down the outer surface of the arm and fore-arm in the distribution of the fifth and sixth cervical roots.

Although the lesion is often situated in peripheral nerves, especially the long thoracic and the suprascapular, and many other cases present themselves as lesions of the fifth and sixth cervical roots, in a few cases the distribution of the paralysis is explicable only in terms of a lesion situated within the cord itself (Parsonage and Turner, 1948).

No specific treatment has been discovered. Relaxation and rest of the affected muscles should be obtained by appropriate splinting, which must be removed twice a day to allow the joints to be moved passively through their full range. Galvanic stimulation of the paralysed muscles has been employed to maintain their bulk.

Complete recovery not invariably occurs, for in a minority residual weakness and even complete loss of power of the affected muscles remains permanently.

This disease, of uncertain aetiology, has not been uncommon among all groups in the army, and has caused a protracted illness which in some cases has led to a permanent disability necessitating invalidment.

DEFICIENCY POLYNEURITIS

Neuritic beri-beri has been described earlier (Neurological Syndromes in Repatriated POW) in this chapter. It undoubtedly occurred in many examples of the marasmus syndrome, but was over

shadowed by other more prominent features of that condition. In an Indian infantry battalion withdrawn from operations for the relief of Kohima in September 1944, in which malnutrition had taken a severe toll of the vegetarian Jat companies, peripheral neuritis was found in 64 per cent. of the 42 worst cases (Walters, 1947).

Among serving soldiers neuritic beri-beri was usually limited to the lower limbs and was mainly sensory in character. Paraesthesia was often confined to the distribution of the common peroneal nerve, and weakness in the muscles of the anterior tibial group resulted in foot-drop. Diminution in sensation was usually demonstrable along the outer margin of the foot and over the toes, the muscles were somewhat tender on squeezing, the ankle jerks were lost and the activity of the knee jerks diminished.

The neuritis disappeared concurrently with improvement in the general condition and did not appear to be influenced by a thiamin supplement in addition to that naturally present in a full diet.

In contrast to the returning prisoners, lesions of the long tracts of the spinal cord were not found, and eye changes were limited to xerophthalmia and night blindness attributable to vitamin A deficiency resulting from low intake and steatorrhoea.

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APPENDIX A.

Notes on Neurosurgery and Peripheral Nerve Injuries

NEUROSURGERY

Administration: In April 1942 two mobile neurosurgical units (Nos. 2 and 3) were despatched from Britain for service in India. Each consisted of four medical officers (one neurosurgical specialist, one neurological specialist, one anaesthetist and one general duty officer), two nursing sisters and six other ranks and was equipped with a 3-ton truck fitted with special operating room equipment (including diathermy and electric generator). On its arrival in May 1942, No. 3 Mobile Neurosurgical Unit commanded by Major R. Johnson, RAMC was attached to No. 14 BGH at Bareilly, where it remained until its transfer to the Fourteenth Army in November 1943. No. 2 Mobile Neurosurgical Unit commanded by Major Hooper, RAMC, also arrived in May 1942 and, (heavy casualties being expected in Southern India at that time), was attached to No. 3 IBGH(BT) at Poona. During the long interval before operations on any considerable scale were commenced in Burma these units were occupied in the care of such few head injuries that reached them, in a considerable bulk of peripheral nerve injury work and in the assessment and treatment of neurological conditions. No. 3 Mobile Neurosurgical Unit moved to Imphal in November 1943 and was attached to No. 43 IGH. Cases were received from the Tamu and Tiddim fronts under considerable difficulties. The journey in the majority of cases took five days, partly spent in river sampan, partly in jeep over jungle tracks, and a final journey by ambulance car over rough roads. In some 'boxes' evacuation was impossible for two to three weeks. With the opening of the Japanese offensive in Assam the threat to the lines of communication made it necessary to withdraw No. 3 Mobile Neurosurgical Unit. Accordingly on 14 March the personnel of the unit, 20 of its cases and its essential equipment were flown in one plane to Comilla. The transport and remaining equipment proceeded by road via Kohima to rejoin the unit a week later. The consultant surgeon, Eastern Command and Fourteenth Army arranged for the unit to occupy the section hospital at Comilla, administered by No. 92 IGH. It soon became apparent that this hospital could not provide the necessary personnel, particularly RAMC for the efficient running of the unit, and on 2 May DDMS, Fourteenth Army directed that a Comilla wing administered by No. 14 BGH should accommodate the mobile neurosurgical unit as well as the eye and dental departments of that hospital and a small burns centre. IORs were provided from local resources and the arrangement worked well. The close association of neurosurgical unit and an eye department proved of mutual benefit. Some permanent buildings were used, but the lack of air-conditioning of the operating theatre was a serious defect that took four months to rectify.

In August 1944, No. 14 BGH again became the parent hospital although the eye and dental centres continued. Owing to a shortage of independent generating sets for X-ray work, the X-ray apparatus was dependent upon the already overloaded Comilla power station. Sufficient current to take an X-ray was not available until 2200 hours each day, so that operations, held up until the necessary X-ray of the skull had been taken, had to take place at night. Early in 1945, working conditions were eased by the installation of special generating set and additional air-conditioners. In September 1944, six members of the Voluntary Aid Detachment replaced Auxiliary Nursing Service nurses. No. 3 Mobile Neurosurgical Unit remained in Comilla until August 1945, when it was withdrawn to India for replacement. It had then handled over 3,000 cases, chiefly of head wounds and mostly in the last period of a year and nine months. On its officer commanding himself, the only recognised neurosurgeon, ultimately fell the additional burden of administering 200 beds, chiefly of seriously ill cases, and of three attached units, and of training four neurosurgeons and a large number of nurses. No. 2 Mobile Neurosurgical Unit, was moved from Poona to Dacca on 16 February 1944. A certain number of head cases were flown to Dacca from Imphal and the Arakan through late February and early March, when the unit was posted to join No. 66 IGH(C) at Dimapore in Assam. During a period of heavy fighting in April this unit received all the casualties from the Kohima area (56 miles by road). On the night of 18 April 1944 following the relief of the Kohima garrison 600 casualties were admitted. Throughout this period urgent general surgery was carried out by the unit in addition to care of the more serious head cases. All nursing officers were ordered to withdraw on 9 April 1944 owing to close proximity of the Japanese and the nursing of cases was a difficult problem for the next three weeks. The hard work of all the personnel and the well-designed equipment of the unit proved of great assistance to the parent hospital in this critical period. Following the advance along the Kohima-Imphal road and the relief of Imphal, No. 2 Mobile Neurosurgical Unit moved first with No. 66 IGH to Manipur Road which gradually ceased to have importance as a line of evacuation after July 1944. It was, however, not possible to move the unit until December 1944, when it worked for a short time at Panitola (north-east of Assam). No. 2 Mobile Neurosurgical Unit proceeded to Inbaung and later into Burma following the general advance to Meiktila which was reached in June 1945. These forward locations enabled head cases to be operated upon within 24 hours of wounding and to be evacuated by plane to No. 3 Mobile Neurosurgical Unit at Comilla. After the fall of Rangoon the unit remained at Meiktila until the end of September dealing with small groups of casualties from the Shan Hills, and then moved to Rangoon where it was set up in No. 52 IGH.

The aim of the neurosurgical units had been to receive cases of head injury within 72 hours of wounding. This was not often achieved. The nature of the terrain prevented any rapid transport, and from the Special Force cases were received very late by various routes. Surgeons working with CCS and in forward field hospitals had been instructed

to evacuate cases to a neurosurgical unit without operation provided they could do so within 3 to 4 days. Talks were given to mobile surgical units, and head injuries were made third in order of priority for air evacuation. In 1944 over 90 per cent. of wounds of the head associated with penetration of the dura were treated by one or other of the two neurosurgical units.

It had been anticipated that in the event of serious resistance by the Japanese in Malaya a fresh neurosurgical unit would be required. No. 7 Mobile Neurosurgical Unit was brought out from the United Kingdom in June 1945. This unit was larger than Nos. 2 and 3, having two neurosurgeons, two anaesthetists and two general duty officers as well as six nursing officers and ten other ranks. The equipment was arranged so that the unit could work in two sections on the plan found successful in Europe. The advance section, after preliminary difficulties in securing equipment, left India with the XXXIV Corps and landed in Malaya on 11 September 1945. The coincident surrender of Japan forced the abandonment of the plan to send the rear section with the Fourteenth Army. In November 1945, the rear section of No. 7 Mobile Neurosurgical Unit was reformed into a new No. 3 Mobile Neurosurgical Unit, and sent to Singapore. No. 7 Mobile Neurosurgical Unit was then disbanded.

The departure of mobile neurosurgical units from India in 1943-44 left the India Command without neurosurgical facilities. In February 1944, a Neurosurgical Centre (India) was planned, to receive head cases evacuated to India from the forward mobile neurosurgical units and to receive cases from within the India Command. The establishment sanctioned in June 1944, allowed besides a specialist in neurosurgery, a neurological specialist from the pool of neurologists, and a stenographer corporal, and allowed an anaesthetist, theatre sister and general duty officer from the strength of the parent hospital. A small scale of equipment was drawn up. Great difficulty was found in obtaining a diathermy apparatus and electric sucker, which were at last delivered in July and August 1944. The neurosurgical centre was attached to No. 126 IBGH (BT) Poona. Indian cases were admitted to No. 7 IBGH (IT). This centre received 41 cases by 31 July, 1944, and 129 cases in the last six months of 1944. The battle injuries were cases requiring late attention (average duration four months) for indriven bone fragments, sepsis, etc. There were three cases of late abscess. Pressure on No. 3 Mobile Neurosurgical Unit at Comilla forced early transfer of cases to the neurosurgical centre, but there was at first great delay in transit. In December 1944, the neurosurgical centre was moved from Poona to Secunderabad [attached to No. 134 IBGH (BT)], and an arrangement of trains was made by which patients could be transferred from Comilla to Secunderabad in seven days or less. Air transport was seldom available in these months. The centre continued in Secunderabad throughout 1945, being given a separate establishment for a neurosurgical assistant, and theatre sister in September.

Of the many difficulties which beset the mobile neurosurgical units in the field, one in particular requires special mention. These

units were designed to be attached to a CCS or forward hospital on which they were to be dependent for all administration, messing and accommodation of staff, besides the ward accommodation for patients and their nursing. The degree to which these services can be spared depended on the degree of activity of the parent unit, but it is obvious that if head cases are numerous, general cases are likely to be even more numerous. The difficulties in evacuation in Burma were exceptional, but the difficulty in organisation is none the less present in less onerous circumstances. Relief from pressure by the provision of further units was out of the question. Addition to the establishment was not possible, and in greater or less degree both Nos. 2 and 3 Mobile Neurosurgical Units carried a burden of administration and nursing for which they were not intended, and this in varying degree for a period of approximately two years.

The administration of the neurosurgical units and centre came directly under the advice of the consultant neurologist, India, who worked in close collaboration with the consultant surgeons India, Twelfth Army and ALFSEA throughout.

At various times Indian nurses were transferred to the neurosurgical centre at Secunderabad for special training. Though they found the long hours in the operating theatre, and the post-operative care of head and spinal cases extremely arduous, these ladies were enthusiastic and receptive.

Clinical Neurosurgery : The policy underlying the establishment of forward mobile neurosurgical units was derived from the necessity for operation on penetrating head wounds within 72 hours of wounding by trained personnel adequately equipped with suction and diathermy. This policy justified itself in the campaign in the Middle East, but was even more necessary in Burma, where the ubiquitous *B. coli* infected nearly all deep wounds. In the early stages of the campaign the terrain was such that the difficulties of transportation limited greatly the range of activity of such units. As air evacuation improved, the mobile neurosurgical unit was able to stay a greater distance from the lines, and to rely on air lift to reduce the time between wounding and operation. Nevertheless, it proved of great value to maintain No. 2 Mobile Neurosurgical Unit in Burma and No. 3 Mobile Neurosurgical Unit at Comilla. In the beginning the mortality from head wounds in Burma was extremely high, even when the interval between wounding and operation was reduced. This was traced to the frequency of *B. coli* encephalitis and meningitis. Careful study of fatal cases yielded a wealth of information as to the natural history of this complication and in particular to the haemorrhagic ependymitis which almost invariably accompanied it. Not only were supplies of penicillin restricted but the efficacy of this agent and sulphapyridine were also slight against this organism. When sulphamerazine and sulphamethazine became available these too were ineffective in the dosage recommended. Lieut.-Colonel Johnson and his colleagues carried out studies of blood levels of the drug in the field, and eventually were encouraged to use heroic dosage with success in controlling the dread infection. The craniotomies

carried out under great difficulties began at last to achieve the desired results and in 1945 a steady flow of cases moved from Comilla to the neurosurgical centre in Secunderabad for final cranial repair and convalescence.

Only in the later stages were the operating rooms air-conditioned, and through the greater part of the campaign it was not possible to operate under local anaesthesia because the patient could not bear the discomfort of being covered with sterile drapes in the high humidity of the operating rooms.

The base area neurosurgical centre at Secunderabad had less difficulty in securing special equipment and its problems were less urgent. Major Hannah, RAMC secured excellent results in repair of cranial defects, and was able to undertake the operative treatment of cerebral tumors, fractured spines and disorders such as prolapsed intervertebral discs referred from base hospitals all over India.

PERIPHERAL NERVE INJURIES[1]

Administration : Up to November 1943, the majority of peripheral nerve injuries from the Arakan were transferred to No. 3 Mobile Neurosurgical Unit in Bareilly. Before the movement of this unit to a forward area at the end of 1943 a centre for peripheral nerve injuries, with Indian and British wings, was planned. It was agreed that each wing of the centre should be attached to an orthopaedic hospital, both because a high proportion of nerve injuries are complicated by bony damage, and to make use of the existing facilities for physiotherapy rehabilitation and occupational therapy. Major A. J. Slessor, RAMC, an officer with special experience in this branch of surgery in Britain and South Africa arrived in November 1943, and took charge of the centre, which opened in No. 3 IBGH(BT), Poona in that month. Indian cases were accommodated in No. 7 IBGH(IT), Kirkee. After a period of training with Major Slessor, Major Pasricha, IAMC took over entire charge of the Indian wing in July 1944. The work of the centre was supervised by the consultant neurologist and consultant surgeon, India. Owing to the difficulty in finding accommodation the British section was transferred in May 1944, to No. 126 IBGH(BT), Poona where it had 150 beds for other ranks and 40 for officers. By July and August 1944, the centre was working to capacity. Cases of peripheral nerve injury were specially labelled by field units and instructions were issued that operations on nerves were not to be carried out except in the centre. The policy of evacuating to the United Kingdom all British cases where there was good evidence of a complete division of a nerve was adopted. Exceptions were made of cases where associated sepsis or other injury prevented departure within the optimum time for operation on the nerve (five to six months). Cases showing signs of recovery within three months were retained in the hope that they would eventually be fit for duty. All Indian cases had to be retained in hospital owing to lack of other facilities for continued treatment. An

[1]See also chapter XXXV.

arrangement was made with the Queen Mary Technical School adjoining No. 7 IBGH for suitable cases to be taught some trade. In view of change in the roles played by the parent hospitals, the British troops wing was transferred to No. 128 IBGH(BT), Secunderabad on 19 December 1944, and the Indian Wing to No. 147 IBGH (IT), Kirkee, in December 1945.

Clinical : The work of the peripheral nerve injury centres followed established orthopaedic and neurological principles. The chief interest in the clinical material lay in the high proportion of causalgia consequent upon nerve injuries in India. The incidence of this complication was more than twice that reported in Britain, South Africa and the USA. It was notable also that causalgia was much less frequent in the cooler hill stations. Major Slessor discovered early the favourable effect of sympathetic ramisection for this condition. After a preliminary trial of novocain injection in each case, large numbers of cases were 'ramisected' with complete relief of pain. Few cases required nerve grafts, and mobilisation of nerves was in general sufficient to enable direct suture. Following the introduction of penicillin many cases of nerve section were sutured in forward areas, especially Comilla, with excellent results.

CHAPTER XVIII

Primary Atypical Pneumonia

Infections of the respiratory system were one of the greatest cause of morbidity in the armed forces of India in the Middle East although the mortality rate was low.

In one Indian general hospital (No. 10 IGH) out of a total of 2,984 medical cases admitted during the year 1941, 763 cases were those of respiratory infections, which means 25 per cent. of medical cases as compared to 3-4 per cent. of these affections in India.

The cause of this increase is difficult to assess. It may have been due to rapid change in temperature and humidity. In many cases these attacks recurred frequently and there seemed little doubt that the mucous membrane was damaged by each attack thus rendering it more liable to further infection and giving a type of patient who repeatedly came to the hospital suffering from the same form of bronchial infection.

Large percentage of these cases were of broncho-pulmonary affections. Cases of pneumonia conforming to the classical description comprised only about 5 per cent. of total number of acute pulmonary affection, the majority of other cases being of some form of bronchitis.

There was also considerable increase in the prevalence of primary atypical pneumonia. It constituted 2-3 per cent. of total cases of respiratory infections admitted in a general hospital. This increased incidence provided both the stimulus and the opportunity to gain a better understanding of this disease. The group of cases of primary atypical pneumonia could be recognised both clinically and radiologically as a separate definite entity and gained a good deal of importance both on account of its unusual course and its close resemblance to pulmonary tuberculosis.

Historical : Bartels (1861) was probably the first one to describe the clinical condition. Cases of the same disease were observed and reported by Gallager (1934) and by Saye (1935) from Spain. In the same year Bowen (1935) has also recorded an outbreak of acute influenzal pneumonitis in a military camp at Hawai and possibly these cases belonged to the same group. A year later Allen (1936) in the USA described an identical condition which he labelled as acute pneumonitis.

In the United Kingdom, Scadding (1937) and later Ramsey and Scadding (1939) gave a comprehensive review of a group of cases, some of which were undoubtedly examples of this condition.

Outbreaks of the same clinical syndrome in American colleges were reported by Bock (1938).

During World War II, Sarwar (1941) observed a series of such cases in No. 10 IGH (MEF) and described 25 such cases at the conference of medical specialists and officers-in-charge medical divisions,

MEF held at Cairo in 1941. At the same conference Scadding (1941) contributed a further series and discussed its aetiology.

Herxheimer and Macmillan (1942) emphasised the main incidence of the disease in young adults and its occurrence in a boys' school.

Later in 1943, Drew, Samuel and Ball published a comprehensive review of the subject.

In 1944, the outbreak of the same disease assumed an almost epidemic form at Camp Claiborne in America and Dingle, Abernethy, Badger, Buddingh, Feller, Langmuir, Ruegsegger and Wood (1944) fully investigated it. Since then much of the work has been done both in the United Kingdom and USA.

Epidemiology : The disease seems to have a definite seasonal incidence. This, however, does not conform with the seasonal incidence which is characteristic of the classical forms of pneumonia. Table I below gives the analysis of 150 cases observed in No. 10 IGH, MEF during the years 1941-'43.

TABLE I

Analysis of 150 *cases of primary atypical pneumonia observed in No.* 10 *IGH, MEF during* 1941-43.

Year	Number of Cases in months												
	January	February	March	April	May	June	July	August	Sept-ember	October	Nov-ember	Dec-ember	Total in one year
1941 ...	2	7	12	2	...	...	1	1	5	10	8	2	50
1942 ...	...	4	16	2	...	...	...	1	1	18	6	...	48
1943 ...	4	5	18	6	2	2	...	...	1	14	...	...	52
Total number of cases in each month	6	16	46	10	2	2	1	2	7	42	14	2	150

It will be observed that there are two peaks in the incidence of the disease. The first peak is during the months of February and March and the second is during the months of October and November each year.

It is interesting to note that the high incidence corresponds to a time with the change in weather conditions and is also at a time when the incidence of other virus infections is at its maximum.

Aetiology: The investigations of atypical pneumonia made during the war have shown that this clinical syndrome can be produced by a number of infective agents, most of which are viruses allied to influenza, and psittacosis. The latter virus is now known to occur in many types of birds including pigeons, chickens and others and it is possible that infection may arise from this source by way of dried droppings inhaled

as dust. At the same time it will be seen that *Rickettsia burneti*, the cause of Q fever as well as *Coccidioides* mites can produce pulmonary lesions indistinguishable from those of primary atypical pneumonias. Lung lesions resembling this syndrome are seen in typhus fever, and more rarely in Rocky Mountain Spotted Fever, South African Tick Bite Fever and experimentally produced *Fievre boutonneuse*.

Primary atypical pneumonia would thus appear to be a syndrome and not a specific disease. The clinicians would probably disagree with this statement. They would exclude cases due to viruses of psittacosis group, as well as those caused by *R. burneti*, Q fever and typhus fever, reserving the term primary atypical pneumonia for those cases, usually mild and often occurring in outbreaks and small epidemics, corresponding to the clinical manifestations described below and the majority of which appear to be due to the virus of Eaton, Meiklejohn and Van Herrick, (1944).

This attempt will certainly break down the conglomerate mass of atypical pneumonias into a number of aetiological entities.

As the knowledge of the causation of atypical pneumonia has not yet been finalised, it is essential at this stage to consider the role and relationship of the various viruses which are capable of producing identical lung lesions.

ROLE OF VIRUSES OF THE PSITTACOSIS GROUP

Even before World War II, it was recognised that natural infection with the virus of psittacosis occurred in birds other than those of the parrot family. Fulmar petrels on the Faroe Islands, the domestic pigeon, domestic fowl and the duck are all subject to natural infection with this virus.

Baker (1942) has also described a variety of cat pneumonia caused by a virus of the psittacosis group. The opportunity for infection of man is thus no longer as restricted as it was at one time thought to be.

The viruses of psittacosis, ornithosis, meningopneumonitis, the virus S.F. of Eaton, Beck and Pearson (1941), and the cat virus of Baker, though distinguishable from one another by certain means (Beck, Eaton and O'Donnell, 1944 ; Rake and Jones, 1944) are closely related and probably belong to psittacosis group.

In 1941, Eaton, Beck and Pearson described an outbreak of six cases of atypical pneumonia. Three of these cases died. They were able to isolate a virus of psittacosis group from four of these cases and psittacosis antibody developed in three of them. In addition to the severity of these cases, other features of the outbreak were the absence of any connection with disease in birds and the readiness with which the infection passed in man. Three of the infected patients were nurses who looked after the initial case and the other two were laboratory workers studying the virus. It is this virus to which the designation S.F. has been given (Eaton, Beck and Pearson, 1941). The readiness with which this virus passed in man is responsible for the suggestion that it represents a virus

of the psittacosis group which has become adapted to man. (Meiklejohn, Beck and Eaton, 1944).

Smadel (1943) investigated 45 sporadic cases of clinical atypical pneumonia occurring in urban populations in the USA and demonstrated a rising titre for psittacosi santigen by the complement-fixation test in nine patients; from two patients of these psittacosis virus was isolated.

Meiklejohn *et al.* (1944) have also isolated viruses belonging to this group from the sputum or lung puncture material in 10 out of 250 cases of atypi cal pneumonia.

Further in connection with the serological diagnosis of these human infections work in America has shown that the viruses of psittacosis, lymphogranuloma and meningopneumonitis are all antigenically related ; infection with any one will excite the production of antibody to the others. The relationship extends even to the viruses of trachoma and inclusion conjunctivitis. It follows, as has been pointed out by Smadel (1943) that active psittacosis infection should never be diagnosed on a single high titre finding and that the rising titre antibody should be looked for.

Thomas, Mirick, Curnen, Ziegler and Horsfall (1943) have found that the sera of cases of atypical pneumonia may contain antibody to a variety of normal tissues in addition to virus containing tissues; serological tests made with sera from this disease with a view to establishing its virus aetiology must be adequately controlled. Despite these pitfalls there is good evidence that viruses of the psittacosis group are responsible for some cases of atypical pneumonia (Favour, 1943 ; Smadel, 1943).

R. burneti (*Q fever*) : Interest in this agent as a cause of atypical pneumonia was first aroused when Dyer, Topping and Bengston (1940) isolated this rickettsia from the spleen of a fatal case ; the infection was contracted in the laboratory. In the later years of war considerable epidemic of Q fever, in which pulmonary consolidation was a constant feature, occurred in the Allied troops in the Mediterranean area (Robbins and Ragan, 1946). In the epidemic at Camp Patrick Henry, Virginia, in American troops returning from Italy, 90 per cent. of the 143 cases showed pulmonary infiltration.

Robbins, Gould and Warner (1946) studied eight outbreaks and came to the conclusion that the infection occurred at about the same time and in the same locality in troops billeted in farm buildings, usually hay barns in which dust was in abundance. There was no evidence suggestive of insect transmission. *R. burneti* was isolated from some of the cases by intraperitoneal inoculation of guinea-pigs with blood (Robbins, Rustigian, Snyder and Smadel, 1946).

The same workers were successful in infecting the embryonated egg direct from the patients by the inoculation of 0·5 cc. of defibrinated blood into the yolk-sac, and the cerebrospinal fluid was shown to be infective in one case by guinea-pig inoculation. These Italian strains of *R. burneti* were without effect on mice when inoculated intranasally or intraperitoneally but they could be maintained by guinea-pig or

egg passage and yolk-sac strains proved infective for white rats and hamsters (Robbins *et al.*, 1946). Antigens prepared with Italian strains fixed complement with sera from the American, Italian and Balkan cases of Q fever, but although antigen prepared from American strains fixed complement well with sera from American cases yet they reacted poorly with sera provided by cases of Q fever from the Mediterranean area (Robbins *et al.*, 1946).

In an experimental study of strains of *R. burneti* from Australian, American and Mediterranean sources, Topping, Shephard and Huebner (1946) found that whilst all gave complete cross-protection in the guinea-pig, American strains were less good antigens than the others when used for producing antisera.

Virus of Lymphocytic Choriomeningitis : Smadel, Green, Paltauf and Gonzales (1942) described two unusual fatal cases of lymphocytic choriomeningitis with pulmonary consolidation. As a result of this it has been considered as a possible cause of atypical pneumonia. Reimann, Havens and Price (1942) described one of four cases of atypical pneumonia, all clinically similar, the serum of which collected on the seventh and twentieth days gave strong protection against lymphocytic-choriomeningitis virus. Smadel (1943) obtained no evidence that this virus was concerned in the aetiology of any of the 45 sporadic cases of atypical pneumonia studied by him.

Virus of Stokes, Kenney and Shaw (1939) *:* This virus was obtained from the sputum of cases of atypical pneumonia by the inoculation of ferrets and mice. After several passages in mice the virus was lost and its relation to the human disease remained undecided.

Virus of Weir and Horsfall Pathogenic to Mongoose : In 1940, Weir and Horsfall isolated this virus from patients with acute pneumonitis. It produced pneumonia in mongoose and could be maintained with some difficulty by passage in this animal. No other species of animal proved susceptible. This virus has not subsequently been found in atypical pneumonia.

Primary Virus Pneumonitis of Infants: Adams (1941) described an outbreak of primary atypical pneumonia which occurred in infants in the University Hospitals of the Minnesota Medical School. It was highly infectious and resulted in 32 cases. Nine of these cases ended fatally.

No virus was isolated but the disease was attributed to an agent of this kind on account of its high infectivity, the absence of a bacterium which could be incriminated and the histological changes found in the lung on post-mortem. The pneumonia was of the interstitial type and cytoplasmic inclusion bodies were demonstrated in the bronchial and alveolar epithelial cells. The source of infection was not determined, nor have similar outbreaks been reported.

Pneumonia Virus of Blake, Howard and Tatlock (1942) *:* In 1942, these workers reported having isolated a virus from cats suffering from pneumonia in a household in which human cases of atypical pneumonia were occurring at the same time. The virus could be passed serially

in kittens, but would not infect mice, thus differentiating it from cat pneumonia of Baker (1942), which was isolated by mouse inoculation and belongs to the psittacosis-lymphogranuloma group. Neutralisation tests with patient's sera suggested that the human and feline cases in this household outbreak were of similar aetiology.

Virus of Eaton, Meiklejohn, Van Herrick and Talbot: Eaton, Meiklejohn, Van Herrick and Talbot (1942) successfully isolated a virus from cases of atypical pneumonia by intranasal inoculation of cotton rats (*Sigmodon hispidus*) with sputum obtained early in the disease. Pneumonic lesions developed in the inoculated animals with considerable regularity and were absent from control animals receiving a variety of materials, including heated sputum by the nasal route. Some difficulty was found in establishing this virus in cotton rat ; and there was some doubt as to the identity of the established virus with that present in the starting material, since antisera made with the former neutralise it well, whereas the results with human convalescent sera were irregular and unconvincing. Subsequent work confirmed this doubt (Eaton, 1945) ; the virus apparently established in the cotton rat, was in all probability latent in the animals.

Eaton *et al.* (1944) have also shown that by the amniotic inoculation of 12-day chick embryos with filtered sputum a virus can be isolated from atypical pneumonia. Unfortunately little or no change was visible in the infected embryo and reliance had to be placed by inoculation of hamsters and cotton rats with the egg material in order to demonstrate the virus. Lung lesions developed in about 75 per cent. of the nasally inoculated animals. Neutralising antibodies for this agent were demonstrated in sera from human cases of atypical pneumonia and their development followed the course characteristic of specific antibodies. These factors certainly are in favour of the virus being the cause of atypical pneumonia.

It may be of interest to mention here the experimental work done by Dingle (1945) and Vance, Scott and Mason (1943) during the war with a view to elicit the correct aetiology of atypical pneumonia.

In the first experiment made by Dingle and his colleagues (Commission on Acute Respiratory Diseases, 1945) the object was to see whether the disease could be transmitted in man experimentally. Pooled and unfiltered sputum and throat washings from seven cases of atypical pneumonia were sprayed into the nose and pharynx of 12 volunteers. Ten developed respiratory illness 7 to 22 days later. Eight of these had fever and five of them developed some degree of pneumonia. Three of these five cases developing pneumonia manifested a rise in the titre of cold agglutinins.

The second experiment (Commission on Acute Respiratory Diseases, 1946) was carried out under strict controlled conditions. In this the inoculum consisted of the pooled sputum and throat washings from six cases of atypical pneumonia. Twelve volunteers received unfiltrated material, 12 received it after filtration, and 18 had the autoclaved inoculum. In each of the two first groups there were three cases of

atypical pneumonia. In the control group there was one case of minor respiratory illness, but since this man was known to have broken out of isolation on more than one occasion and to have gone into the room occupied by one of the volunteers, who developed and was suspected of atypical pneumonia, his illness was of dubious significance.

The incubation period in the group receiving the filtrate was more (9-15 days) than the group getting the unfiltered sputum and throat washings (5-8 days). There seems no doubt from this experiment that primary atypical pneumonia of unknown aetiology can be transmitted experimentally in man, that the agent is filterable and in all probability a virus.

RELATIONSHIP OF VIRUS OF ATYPICAL PNEUMONIA TO THE VIRUS OF INFLUENZAL PNEUMONIA

The work on influenza has proved conclusively that lung lesions are caused by a virus ; but all attempts to establish a relationship between the influenza virus and primary atypical pneumonia have failed.

MORBID ANATOMY AND HISTOLOGY

The death-rate in atypical pneumonia has generally been very low. There have, however, been a few fatal cases of atypical pneumonia of undetermined aetiology and these have been the subject of careful post-mortem examination (Needles and Gilbert, 1944 ; Glendy, Beaser and Hankins, 1945 ; Campbell, Strong, Grier and Lutz, 1943 ; Golden, 1944).

Lungs: The picture presented was one of acute interstitial pneumonia. Pleural surfaces have been smooth and the lungs large but not manifesting any clearly palpable area of consolidation. On cut surface the affected areas have been deep red ; and from the bronchial passages an exudate, which was either thin and blood-stained or viscid or even creamy, could be expressed.

Microscopically the affected areas showed thickening and infiltration of the alveolar walls with predominantly mononuclear cells. The alveoli contained an exudate composed of serum, fibrin, red corpuscles, mononuclear cells, occasional polymorphonuclear leucocytes, and desquamated alveolar epithelium. Areas of collapse occur, and a feature of the alveolar exudate was the variation in its composition from one part of the lung to another. The bronchioles showed thickening and infiltration of their walls with mononuclear cells which tended to extend radially into the regional interstitial tissue (Golden, 1944). The contents of bronchioles consisted of mucoid material containing desquamated and degenerated epithelial cells.

Central Nervous System: In the patients who died with an ascending flaccid paralysis, the cord at the level of eighth to tenth thoracic segments showed extensive perivascular necrosis infiltrated with polymorphonuclear leucocytes. There were fibrin thrombi in the vessels and an overlying neutrophil meningitis (Campbell *et al.* 1943).

Perrone and Wright (1943) have also described a fatal case of atypical pneumonia with encephalitis. In this case the leptomeninges showed no gross change and cerebrospinal fluid was clear. On section the cerebrum showed numerous areas of dark brown colour and pinhead size in both grey and white matter.

Microscopically these areas were seen to be perivascular foci of infiltration with astrocytes and microglia, usually associated with a ring of peripheral haemorrhage. The vessels of the leptomeninges and brain parenchyma were engorged, and scattered ring-haemorrhages without cell proliferation were seen in both grey and white matter.

CLINICAL FEATURES

Incubation Period: Most investigations have surmised that the incubation period is between 7-21 days. In the present series no estimate has been possible.

Clinically this condition showed itself as a transient localised consolidation occurring within the course of catarrhal infection of the respiratory tract. This type comprised of two sub-divisons :—

(i) Those showing a patch of consolidation in one part of the lung throughout the course. This for purpose of description is called the continuous type.

(ii) In contrast to above there was a type in which signs and symptoms showed exacerbation after a period of remission. Radiologically in this sub-group there were rapidly developing opacities in the lung parenchyma disappearing within a few days and often opacities reappearing in the same part or in another part of the same lung or even in the opposite lung with exacerbation of symptoms. This is designated as the 'relapsing type'.

Onset: In the cases observed in the earlier phases of war (in 1941) the onset was usually insidious and the symptoms were often present for a number of days before the patients reported sick. These patients had either an affection of upper respiratory passages or they just complained of malaise, headache and a general feeling of being out of sorts for a few days preceding the actual onset. Cough was always present usually productive, associated with a fair quantity of mucoid or mucopurulent sputum. In about 20 per cent. cases it was blood stained. Vague pains in the chest were often complained of and excessive lassitude and dyspnoea on exertion completed the subjective symptoms of the patient. Later on more attention was focussed on this fascinating clinical entity ; cases were encountered in which there were no respiratory symptoms whatsoever and the condition occurred as a simple pyrexia of unknown origin—often high, and as a rule, continuous for even from 1 to 3 weeks.

In a small number of patients the early symptoms did not fall into the above description. Six cases had an exacerbation of a chronic cough and were originally regarded as cases of pulmonary tuberculosis ; two of these had a sudden onset of pain on respiration and coughing and one of them even presented pleural friction.

On physical examination of the chest :—

(i) (a) There was either complete absence of localising physical signs.

(b) *or* impaired percussion note in a localised patch with absent or distant breath sounds, with or without moist rales.

(c) *or* moist rales only.

(d) *or* no impaired note, no moist rales but only weak breath sounds in a localised area.

(ii) Injection of fauces and pharynx was generally present, even tonsillar enlargement. In fact in few cases originally the diagnosis of acute tonsillitis was made and it was only on account of the persistence of cough and the development later of moist rales at one base that led to further investigation and the correct diagnosis.

(iii) Pyrexia generally was present in all cases. The temperature varied between 100-102° F. and lasted for about a week. In those cases where there was appearance of consolidation later in another part of the same lung or even in opposite lung, there was remission of fever for a few days followed by secondary rise running an almost identical course.

(iv) Respiratory rate was not affected. All these cases followed a benign course in that there was no serious complication and though the patient, had fever, cough, blood stained sputum, etc., there was always complete absence of toxaemia. Even in those cases where temperature was high, respiration rate was not affected and in fact in the majority of cases the patient was walking about in spite of the presence of catarrhal infection.

Complications : None of the cases in this series presented any complication. Other observers have, however, described encephalitis, ascending flaccid paralysis, meningism, rashes, jaundice, small pleural effusions and antral infection as the complications.

The diagnosis was confirmed by an X-ray picture which showed :—

(i) Either wooly area of consolidation, varying from a patch, the size of a shilling and confined to a segment of a lobe to the partial or complete involvement of a lobe. The area of consolidation was less dense and more mottled than in pneumococcal pneumonia.

(ii) *or* there were multiple areas of patchy consolidation. The lesions were not at the same stage of development, i.e., one resolving while another was progressing.

(iii) *or* the affected area showed marked reticulation which was coarse and its pattern often overlaid by a diminished translucency thus giving it a ground glass appearance.

CLINICAL PATHOLOGY

Blood Count : Neither the total nor differential leucocyte count showed an appreciable departure from normal. A few of the cases showed well marked eosinophilia varying from 8 to 11 per cent.

Sputum : Bacteriological examination of sputum as well as that of throat flora did not reveal any bacterium, the presence or predominance of which might have suggested that it was aetiologically concerned.

Cold Agglutinins : The presence of cold agglutinins from group "O" human erythrocytes in the sera of cases of atypical pneumonia was reported independently by Peterson, Ham and Finland (1943) and by Turner (1943) and the suggestion was made that this reaction might prove of diagnostic value. Cold agglutinins are present in low concentration (titre up to 1 in 16) in normal sera. They are known to occur in abnormal concentration with regularity in trypanosomiasis (York, 1910) and their presence in a considerable percentage of haemolytic anaemias has been recognised since the time of early French workers on this condition. It is interesting to note that haemolytic anaemia associated with a high titre of cold agglutinins has been reported as a complication of atypical pneumonia (Finland, Peterson, Allen, Samper and Barnes, 1945 ; Ginsberg, 1946). Further work by Turner and by Finland and their colleagues gave support to the belief expressed in their preliminary communications that the demonstration of an increase in cold agglutinins might be of help in distinguishing between primary atypical pneumonia and other respiratory infections. In the majority of cases in which atypical pneumonia has been diagnosed clinically cold agglutinins were found in sera in increased quantity, and titre, usually over 1 in 80 and sometimes as high as 1 in 2,560 or over, was observed, whereas in a large number of control sera from normal individuals or from patients suffering from a variety of conditions, including infections of the respiratory system such as bacterial pneumonias, influenza, upper respiratory infections and pulmonary tuberculosis, cold agglutinins were either absent or present only in low titre (Turner, Nisnewitz, Jackson and Berney, 1943 ; Finland *et al.*, 1945). Only exceptionally did any of the control sera show abnormal titres and even then they were not high. Among those repeating this work some obtained similar results. Humphrey (1944) found that 93 per cent. of 14 patients with atypical pneumonia developed cold agglutinins in abnormal amount whereas none of 80 controls did so, and Spingarn and Jones (1945) found titres ranging from 1 in 224 to 1 in 14,000 in all of 91 cases of atypical pneumonia. It is interesting to note that the latter workers put the upper limit of cold agglutinins in normal sera as 1 in 224, considerably higher than other investigators, and that they demonstrated cold agglutinins in titre ranging from 1 in 224 to 1 in 3,384 in six out of seven cases of glandular fever. Measles, scarlet fever and the orchitis of mumps provided occassional titres above the normal level. Favour (1944), on the other hand, found titres of 1 in 160 or over in only 18 of 46 cases of atypical pneumonia, and Horstmann and Tatlock (1943) found the test positive in 27 out of 43 cases. The American commission on acute respiratory diseases (Dingle, 1944) obtained positive reactions in 25 to 50 per cent. of cases and in a later communication, Dingle (1945) states that the proportion of positive reactions had varied from 30 to almost 100 per cent. in the different series examined. This would naturally suggest that only some, or possibly only one, of

the agents producing the clinical picture of atypical pneumonia excite the production of cold agglutinins.

In this connection it is interesting to note that Eaton (1945) has also drawn attention to the absence of any abnormal concentration of cold agglutinins in the sera from cases of atypical pneumonia due to viruses of the psittacosis group. Caughey and Dudgeon (1947) have observed that cold agglutinins are not increased in atypical pneumonia due to *R. burneti* and Eaton (1945) is of the opinion that an increased titre of cold agglutinins is probably confined to those cases of atypical pneumonia due to the virus isolated by Eaton *et al.* (1944) to which reference had been made earlier.

There seems to be general agreement that the development of cold agglutinins in atypical pneumonia follows the course characteristic of antibodies and that their increase is first detectable from the fourth to eighth day of the disease, reaching its maximum between the third week and falling again rapidly during convalescence. They disappear gradually from sera stored in the refrigerator, but the titre can be maintained unchanged for even six months if sera are stored at 70° C.

DIAGNOSIS

The mainstay of diagnosis lies on radiological findings. Points which are of importance in clinical diagnosis are :—

(i) General well-being of the patient.

(ii) Physical signs either indefinite or very often resembling pleural effusion, atelectasis and unresolved pneumonia.

(iii) Respiratory rate is not affected.

(iv) Blood count is normal.

These cases revealed a few pitfalls in the earlier period of war, especially the cases where haziness appeared in upper zone simulated very closely cases of early pulmonary tuberculosis and in view of the unfortunate tendency in the services to board out a man with pulmonary tuberculosis a few of the cases were imprinted with the stigma of tuberculosis and actually evacuated back to India. However, after re-investigation, observation and treatment over a certain period enabled them to get rid of radiological opacities in lung and arrive at the correct diagnosis.

TREATMENT

There was no specific treatment. Sulphonamides and penicillin proved useless. Cough was difficult to control and some cases required the administration of codein phosphate and linctus containing heroin. In 1949 Meiklejohn and Shragg drew attention to favourable effects of aureomycin in cases of primary atypical pneumonia.

SUMMARY

The above account is based on a survey of the literature and on the personal study of cases of respiratory infections amongst the Indian troops while serving in the Middle East during the years 1939-43. The cause of primary atypical pneumonia is probably virus in origin—virus of Eaton *et al.* (1942). The relationship of this virus with the virus of psittacosis group, *R. burneti*, the virus of lymphocytic choriomeningitis and other allied viruses have been discussed. The disease is probably commoner than is generally recognised ; and a definite diagnosis can be made only by X-ray examination. The main clinical features were cough, headache, malaise and fever associated with area of consolidation in the lung field. Clinically or radiologically it may be confused with influenza, pulmonary tuberculosis and bacterial pneumonia. The disease ran a benign course in the above series of cases observed but complications observed by other authors have been described. Cold agglutinins in high titres have been observed in cases of primary atypical pneumonia. Administration of penicillin and sulphonamide do not affect the course of the disease. Aureomycin was not available at the time.

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CHAPTER XIX

Pulmonary Eosinophilosis

INTRODUCTION

This clinical syndrome has engaged the attention of various civil and military workers during World War II. The condition was seen frequently in the medical wards of general hospitals. It was, however, not in itself a problem of military importance. With the establishment of several 1,000-bedded hospitals in 1942-43, the medical divisions of these hospitals came under the professional charge of senior and experienced physicians. Frimodt-Moller and Barton (1940) and Weingarten (1943) focussed the attention of the physicians on this disease. The latter brought to light the specificity of arsenic in the treatment of the disease. The army physicians were then on the look out for this condition in the chest wards. The diagnosis and treatment of the condition thus became quite frequent. The physicians in civil practice also gradually became familiar with the prevalence of the disease.

A large amount of literature has sprung up around this condition and has been reviewed by Viswanathan (1948) in an article in the *Quarterly Journal of Medicine.* His review includes 685 cases reported by various medical men and detailed observations on 207 of his own cases (civil 18, army personnel 189). This chapter is largely a summary of his paper in some respects and an elaboration in other respects. Free use has been made of all available literature.

Pulmonary eosinophilosis, or tropical eosinophilia as it is more commonly known, is a clinical condition characterised chiefly by cough, paroxysms of expiratory dyspnoea, a raised WBC count with persistent and absolute eosinophilia, often typical radiographic appearances in the lungs, and frequent systemic manifestations such as fever, lassitude and loss of weight. In addition, there is often splenic enlargement, adenopathy and a raised blood sedimentation rate. It is only in the last fifteen years or so that this syndrome has come to be recognised as a separate clinical entity.

In 1940, Frimodt-Moller and Barton reported 175 cases with nodular shadows in X-rays of the lungs, and over 20 per cent. eosinophils in the blood under the title *Pseudotuberculosis of the lung with massive eosinophilia.* Bass (1941) reported three cases in children in the USA. All had massive eosinophilia and miliary infiltrations of the lungs. One of the children died of broncho-pneumonia. In the other two, the condition persisted for years with fever, palpable spleen and lymphadenopathy, but they eventually recovered. These cases presented lassitude, loss of weight, fever, cough, asthmatic attacks, massive eosinophilia, and mottled shadows in the X-ray picture of the lungs. Patients of several races, all ages and both sexes were affected. He emphasised that residence in the coastal areas of India was a factor in the incidence of the disease.

Simeons (1943) observed 35 cases during the course of nine years in India. He described his patients as having cough, fever, enlargement of the liver, lung mottling and eosinophilia. He used the term benign eosinophil leukaemia for this condition.

Chaudhuri (1943) in an editorial review suggested that the paroxysms of cough, eosinophilia and pulmonary infiltrations were the result of an allergic response to some antigen.

Chakravarty and Roy (1943) reported one case in Calcutta which had urticaria in addition to other symptoms.

Treu (1943) reported two cases in Calcutta successfully treated with neoarsphenamine injections.

Vaidya (1943) saw six cases in Bombay from 1929 to 1934. They were all treated with neoarsphenamine. Two of these cases had repeated relapses. Shah, and Heilig and Visveswar also reported cases during 1943.

Emerson (1944) reported a case of tropical eosinophilia in a young American aged 30 years who had returned to the States in 1942, after residing in India for 5 years. The patient was successfully treated with carbarsone.

Parsons–Smith (1944) reported the condition in Egypt in a male European.

Leishman and Kelsall (1944) observed 8 cases in a military hospital in India ; all the patients were Indians or Anglo-Indians who had been living in coastal districts since childhood. All the cases were treated successfully with neoarsphenamine.

Carter, Wedd and D'Abrera (1944) detected different varieties of mites in the sputum of 17 out of 26 persons in Ceylon, 24 of whom were under treatment for various respiratory disorders. In three of the mite-infected patients, an eosinophilia of 38 to 66 per cent. was observed.

Treu (1944) reported six cases in India ; of these one had no respiratory symptoms but had swelling of the glands in the groins and fever. In his series, two members of one family had the disease.

Ritchie (1944) diagnosed the condition in an African from Tanganyika.

Soysa and Jayawardena (1945) investigated 25 Ceylonese patients who showed high eosinophilia, symptoms of respiratory disorder and had mites in the sputum. All responded satisfactorily to arsenical treatment.

Apley and Grant (1944, 1945) reviewed five cases of tropical eosinophilia in England, and were of the opinion that this condition and Loffler's syndrome are indistinguishable.

Lal (1945) reported 15 cases from Bengal. He concluded that tropical eosinophilia was not a separate clinical entity, but was of the nature of allergic pneumonia.

Hirst and McCann (1945) found the condition in a naval officer, who developed symptoms while stationed in Samoa. The patient responded to arsphenamine.

Patel (1945) reviewed 49 cases from Bombay of whom 37 were male and 12 female. He suggested that the condition is an allergic manifestation, the pulmonary interstitial tissue being more sensitive than the bronchi.

Van der Sar and Hartz (1945) reported three cases from Curacao. In one they found microfilaria in the enlarged lymphnodes. Arsenicals cured all the cases. They considered that they had demonstrated filariasis as the cause of tropical eosinophilia.

McGuire (1945) in a discussion on periarteritis nodosa mentioned two American soldiers who developed tropical eosinophilia in an island in the South-West Pacific.

Menon (1945) offered experimental evidence, based on intra-peritoneal injection of guinea-pigs with blood from cases of tropical eosinophilia in support of the infection theory which he postulated. He (1946) observed that the disease has a wide distribution geographically, though the incidence may be higher in certain localities. He offered additional experimental evidence in support of the infection theory.

Van der Sar (1946), under the title pulmonary ascariasis, reported eight cases in all of which he found mites in the sputum. The first four conformed to the description of pulmonary eosinophilosis, while the remaining four were possibly cases of Loffler's syndrome.

Irwin (1946) gave details of two cases who developed the disease while serving in the South-West Pacific theatre of war. Neither had microfilaria in the blood but gave positive intradermal skin test with *Dirofilaria immitis.* He suggested that all future cases should be tested for microfilaria.

D'Abrera and Stork (1946) reported the combination of a positive Wassermann reaction with a negative or doubtful Kahn in about 70 per cent. of cases of this syndrome. They also noticed reversal of serological reactions after treatment.

Hunter (1946) diagnosed the condition in a European after his return to England from Nigeria.

Jhatakia (1946) observed 140 cases of eosinophilic lung. He recorded occurrence of cases in more than one member of a family. On the basis of his observations, he grouped his cases as ambulatory, acute and chronic types.

GENERAL FEATURES OF THE DISEASE SUMMARISED FROM PUBLISHED CASES—CIVILIANS 688 CASES AND ARMY PERSONNEL 204 CASES

GEOGRAPHICAL DISTRIBUTION

Most of the recorded cases have been from India and Ceylon. Inquiries made by Viswanathan (1948) from several medical men and women in different parts of India suggest that many cases of pulmonary eosinophilosis have been observed by the general practitioners,

e.g., 9·7 per cent. of 1,383 cases of respiratory diseases seen at a tuberculosis sanatorium in South India in one year were cases of tropical eosinophilia (Menon, 1946) ; again Viswanathan (1945) found 9 per cent. of 946 cases admitted to hospital for respiratory disorders in North India to be tropical eosinophilia. Cases have also been reported from America, England, North Africa, Tanganyika, China, Australia, Singapore and South-West Pacific islands. Weingarten (1943) thought that the disease was confined to the coastal towns of India but cases have been reported from all over the country, and many of the latter have never been to the sea-coast at all. As there is an exacerbation of the symptoms of the disease during the monsoons, atmospheric humidity may be one of the aetiological features.

RACE, AGE AND SEX INCIDENCE

The disease has been observed at all ages from 1 to 62 years and in both sexes, though the males preponderate. All races are affected. There appears to be no familial or constitutional susceptibility. Economic status and occupation have no aetiological bearing though Carter *et al.* (1944) and Jhatakia (1946) have reported a high incidence in workers in grain stores.

AETIOLOGY

The real aetiology of the condition still remains to be elucidated. There are several views put forward by different observers. These are discussed later.

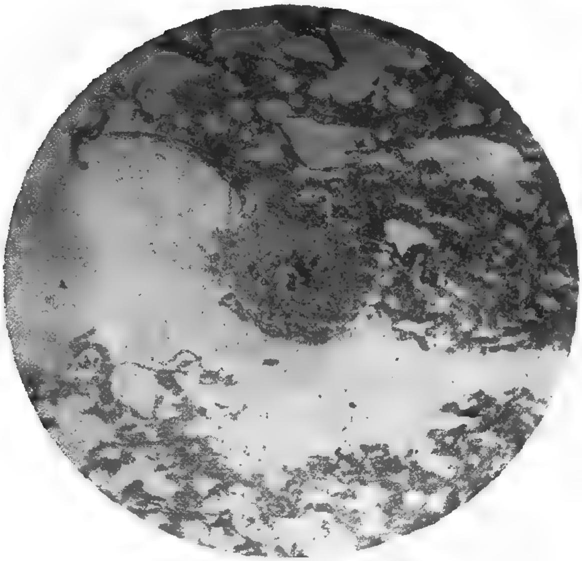
PATHOLOGY

There is only one reported case conforming to the description of pulmonary eosinophilosis on which an autopsy has been made (Viswanathan 1948), otherwise the pathology of the condition has remained obscure. The patient died after the second injection of intravenous neoarsphenamine, arsenical encephalopathy being the cause of death. The findings were as follows :—

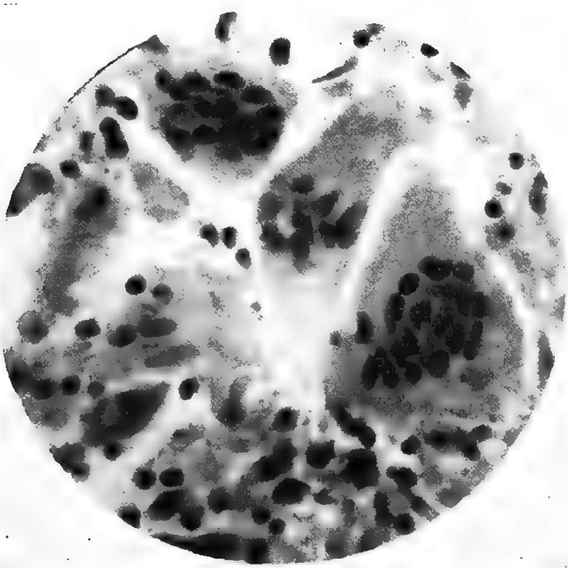
(i) Haemorrhages in the brain, lungs and mesentery—probably due to arsenical poisoning.

(ii) *Lungs :* (a) *Macroscopic :* Recent pleural adhesions that could be easily broken down. Dark reddish-brown areas scattered over the surface and in the substance of both lungs. These varied in diameter from 0·5 cm. to 2·5 cm. across and appeared haemorrhagic in origin, very much like the early stage of infarction. Bronchioles showed congestion of the mucous memberane and contained blood stained mucopurulent secretion. All other organs appeared normal to the naked eye. (b) *Microscopic Examination :* Stained section of lung tissue revealed several areas of interstitial fibroblastic proliferation. The alveoli were lined with swollen cells and their lumina were filled with macrophages. Most of these macrophages contained eosinophilic granules grouped in parts of the cytoplasm. These granule—

PULMONARY EOSINOPHILOSIS



1. Photomicrograph of lung. Nodule in the centre, with a group of giant cells surrounded by monocytes (low power.)



2. Centre of the same nodule under high power magnification showing the giant cells.

Courtesy—*Quarterly Journal of Medicine.*

containing cells were present in large numbers in only some of the alveoli and air passages. Eosinophilic leucocytes were also seen in large numbers in the alveoli and in the interalveolar space. The partially consolidated areas were closely related to the terminal bronchioles. In some of the alveoli, the mononuclear cells had fused together to form very large multinucleated giant cells. In a few areas characteristic nodule formation could be seen. Each nodule consisted of 4 or 5 giant cells in the centre, surrounded by a cluster of mononuclear cells. The histological appearances in this case were suggestive of an infective rather than of an anaphylactic reaction. The lesions were peribronchial and not perivascular. Their nature suggested that the infection in pulmonary eosinophilosis is probably by inhalation and that the infecting agent enters the peribronchial tissue and sets up an inflammatory process involving mainly the interstitial tissue and partially the alveoli. Discrete scattered areas of cellular infiltration, monocytic and eosinophilic, are produced. When the process becomes chronic, nodules containing giant cells and monocytes are formed. The disseminated mottled shadows seen in the radiographs of cases of tropical eosinophilia are probably due to such areas of infiltration with monocytes and eosinophils.

SYMPTOMATOLOGY

Clinically there are two distinct types—the acute and the chronic.

The Acute Type : This is sometimes a self limiting variety in which the condition clears up completely within a short period without any specific treatment or the disease may go to the chronic stage if untreated. The onset is sudden with high fever ranging from 102° F. to 104° F. There is cough and hurried respiration simulating an attack of acute respiratory infection. Physical signs in the lungs are those of acute bronchitis but in a few cases signs of patchy consolidation may be present. One recorded case developed pleurisy with effusion, the aspirated fluid containing eosinophils (Viswanathan, 1948). In about 25 per cent. of the cases the symptoms clear up completely without any specific treatment in four to six weeks ; the remainder pass on to the chronic stage. Only the presence of absolute eosinophilia helps to reveal the true nature of the condition.

The Chronic Type : The mode of onset is gradual. General malaise, lassitude, impaired appetite and a lowgrade fever ranging from 99° F. to 101° F. are the usual presenting symptoms. After a week or two the patient develops a dry cough. The cough may be the first symptom to be noticed. It is unproductive to begin with and comes on in paroxysms particularly at night. After a month or two the patient begins to bring up a small quantity of viscid mucus after coughing or a pellet of sticky mucus. The patient begins to feel breathless after coughing or after exertion. This breathlessness is a more frequent manifestation of the disease than asthmatic attacks but paroxysms of respiratory dyspnoea occur in a very large number of cases and are often mistaken for asthma. In an untreated case of the chronic type, the

febrile period lasts from a few days to two months, while the respiratory symptoms last for a year or more. In a few cases, the disease continues for years in the form of periodic attacks of asthma-like paroxysms. Haemoptysis has also been reported in a very small percentage of cases (20 per cent. in an analysis by Viswanathan, 1948). Physical signs are absent in the lungs during the first few weeks. Later, when there is more expectoration, rales and rhonchi are heard over both sides particularly at the bases. Hyperresonance of the chest is frequently present in the later stages of the disease. Clumps of eosinophils are frequently found in the sputum but not Charcot-Leyden crystals or Curschmann's spirals. Enlargement of the spleen is found in about 50 per cent. of the cases, specially during the febrile period.

Atypical Cases : Here the presenting symptoms may be prolonged. Pyrexia, exhaustion, palpitations precordial pain, lymphadenopathy and enlargement of the liver may occur singly or may occur in combination with respiratory symptoms. Two atypical cases with breathlessness on exertion as the only complaint have been reported (Viswanathan, 1948). The diagnosis is made in these cases by the finding of high eosinophilic counts and the therapeutic response to arsenic.

LABORATORY FINDINGS

Leucocyte Count: The total white-cell count varies from 12,000 to 80,000 per c.mm., while the eosinophil percentage ranges between 20 and 80 per cent. Massive eosinophilia is responsible for the high leucocytosis. The absolute count of the neutrophils remains more or less constant. Immature eosinophils are rarely seen, while overmature ones are frequently met with. Two types of eosinophils, one with well-stained coarse granules, and the other with lightly stained fine granules are seen with equal frequency. The degree of eosinophilia bears no relationship to the severity of the disease. In fact it is the patients with the lower eosinophilic counts that show less dramatic response to arsenic, and are more difficult to treat. Bone-marrow smears show no myelocytic reaction but there is a preponderance of mature eosinophils. As a rule pulmonary signs and symptoms disappear more quickly in response to treatment than the abnormalities in blood counts.

Cold Agglutination of RBC : Viswanathan and Natarajan (1945) have shown that the serum of most cases produces high-titre cold agglutination of RBC.

Blood Wassermann and Kahn : D'Abrera and Stork (1946) and Menon (1946) found positive Wassermann and/or Kahn reactions in some of their cases in the absence of any positive evidence of syphilis. Menon (1946) uses the test as one of the diagnostic criteria, particularly when the serological reactions are reversed after oral administration of stovarsol.

Erythrocytic Sedimentation Rate : In the majority of cases the erythrocytic sedimentation rate is raised.

RADIOGRAPHIC FINDINGS

The typical picture of disseminated mottled shadows distributed throughout both lungs is not consistently observed. The mottling may be confined to one lung or to part of one lung. It may be present only in certain phases of the disease, so much so that X-ray pictures taken at other times may not show any typical appearances. In typical cases the shadows are so uniformly distributed as to suggest a haematogenous spread. X-ray changes are usually seen during the febrile stages of the disease. In cases of some standing, only prominent bronchial markings are found but in some untreated cases X-ray shadows persist for months. One case with atypical X-ray appearance has been described by Viswanathan (1948). This case showed dense mottling in the right upper lobe with a well-defined cavity in the middle, very suggestive of pulmonary tuberculosis. The sputum, however, was repeatedly negative for tubercle bacilli. Blood examination showed a white-cell count of 22,000 per c.mm. with 42 per cent. of eosinophils. The patient was given 8 weekly injections of neoarsphenamine. The temperature became normal after the second injection and all the lung symptoms disappeared after the fourth injection. The mottling in the radiograph completely disappeared in six weeks, leaving behind only a thin ring shadow. At the termination of the course of injections the eosinophils were reduced to 10 per cent. and at the time of discharge two months later to 5 per cent. The sedimentation rate, which was raised at the time of admission, was found to be within normal limits.

DIAGNOSIS

The history of a febrile illness with long continued respiratory symptoms, viz., cough, breathlessness on exertion, fits of bronchial spasm, massive eosinophils with a high total leucocytic count, and mottled shadows in the X-rays of the lungs is sufficient evidence to establish a diagnosis of pulmonary eosinophilosis.

The condition may have to be differentiated from the following:—

Helminthic Infection : By stool examination and exhibition of anthelmintics.

True Asthma with Eosinophilia : Total white-cell count is rarely above normal Chest X-ray does not show the characteristic mottling. Blood sedimentation rate (BSR) is normal and WR is negative. There is no response to arsenical injections.

Loffler's Syndrome: Some writers are of the opinion that this condition is identical with tropical eosinophilia. Here, however, there is absence of systemic disturbances. The pulmonary infiltrations are transitory ; blood changes fluctuate rapidly ; spontaneous disappearance of all signs without treatment is a feature, BSR is normal and the WR is negative. Blastomycosis and coccidioidomycosis may also cause signs and symptoms of pulmonary eosinophilosis.

PROGNOSIS

Untreated cases persist for months or even years with remissions and exacerbations. Arsenic acts as a specific in the majority of cases and response to it is a good diagnostic criterion. A few patients, less than 2 per cent. do not respond fully to treatment, but some amelioration of symptoms is obtained. A few cases show relapse, notably those with low eosinophilic counts, but most of these respond to a second and sometimes a third course of treatment. No fatalities have so far been reported.

TREATMENT

A course of treatment ordinarily consists of 8 to 10 weekly injections of neoarsphenamine beginning with an initial injection of 0·15 g. and continuing with 0·3 g. subsequently. In milder cases a shorter course of 4 to 6 injections may suffice. Successful results are also obtained with oral administration of stovarsol and carbarsone.

DISCUSSION

The exact aetiology of pulmonary eosinophilosis is as yet unknown. Widely divergent views have been expressed by different writers. There are two important questions that have to be answered. These are :—

(i) Is this syndrome a distinct clinical entity ?

(ii) Is it an infective or an allergic process ?

It appears quite definite that the answer to the first question is in the affirmative. Eosinophilia occurs in a large variety of conditions. The consistently occurring combination of fever, loss of weight, cough, breathlessness, and asthmatic attacks, associated with signs of pulmonary infiltration and persistent massive eosinophilia differentiates it from other causes of eosinophilia.

The second question is more difficult to answer. Several views have been put forward by different authors. The following can be briefly considered.

Filarial Infection Theory : This was advanced by Van der Sar and Hartz (1945). They saw three cases of pulmonary eosinophilosis in Curacao. In one of the cases they found microfilaria in enlarged lymphnodes. They considered .that they had demonstrated filariasis as the cause of the condition. This has, however, not been confirmed by anyone else, except Irwin (1946), who gave details of two cases which showed a positive intradermal reaction for filarial antigen only.

Loffler's Syndrome: Loffler (1936) described the condition characterised by transitory migratory pulmonary infiltration associated with peripheral eosinophilia and paucity or absence of systemic manifestations. Several writers have produced evidence to show that this is due to various factors, viz., helminthic infection, inhalation of pollen of certain plants, protozoal infection, etc. Loffler's syndrome appears to be an allergic response to a variety of allergens. In this syndrome there is

absence of systemic disturbances, the pulmonary infiltrations are transitory and migratory, blood changes fluctuate rapidly, and all changes disappear spontaneously without any treatment. The WR is negative and the blood sedimentation rate is normal. The conditions included under the generic name Loffler's syndrome are thus distinct from pulmonary eosinophilosis.

Allergy : Eosinophilia and asthmatic attacks are the points put forward in favour of allergy. Ratner (1943) was of opinion that leucopenia is so characteristic of true serum sickness, serum allergy, long standing anaphylaxis, and drug allergy, that leucopenia can be considered as diagnostic of allergy. While leucopenia occurs in the early stages, eosinophilia is characteristic of the chronic and often repeated expressions of allergy. If the syndrome of pulmonary eosinophilosis is an allergic response, there should be no eosinophilia in its early stages. Cases of sudden onset with no previous history of any type of allergic manifestation were found to have massive eosinophilia from the beginning. It is also stated that during the allergic phase, as for instance in the beginning of an asthmatic attack, there is a sudden fall in the white-cell count as well as the eosinophil percentage. In pulmonary eosinophilosis on the other hand, both are usually raised during an exacerbation.

Mite Infestation : The findings by the Ceylon workers and by Van der Sar (1946) of mites in the sputum of patients with asthmatic symptoms and eosinophilia have suggested that mite infection of the respiratory tract may be the cause of pulmonary eosinophilosis. Carter and D'Abrera (1946) have experimentally produced in monkeys, irregular and spasmodic cough and fluctuating eosinophilia by intratracheal introduction of mites. As against the mite infection theory there are the negative findings of most other investigators. It is possible that the pathogenic agent may be carried by the mite, i.e., the mite acts as a vector. The fauna of the upper respiratory tract in man has by no means been worked out and no precise knowledge of this is available at all.

Infection : Inoculation experiments by Menon (1946) and Viswanathan (1950) afford confirmation of the assumption that pulmonary eosinophilosis is not an allergic response. Injection of blood from patients into guinea-pig produced initial eosinophilia and secondary leucocytosis in ten days. He argued that the changes were not due to anaphylaxis because only one injection of blood was given and leucopenia and not leucocytosis is the usual finding in hypersensitive states. Histological examination of lung sections, showed lesions similar to those reported by Viswanathan (1948) in the only case that has come to autopsy in man. The pathological changes in the lungs of the experimental animals closely resemble lesions produced by McCordock and Macenfuss in the lungs of animals infected with vaccinia and influenza virus. These findings suggest the possibility that the aetiological agent in pulmonary eosinophilosis may be a virus. Further arguments in favour of the theory of infection are the fever, adenopathy, splenomegaly, elevated blood sedimentation rate and the dramatic response to arsenic.

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CHAPTER XX

Psychiatry in the India Command, Fourteenth Army and ALFSEA

ORGANISATION BEFORE THE WAR

The outbreak of World War II found the medical services in India and elsewhere almost totally unprepared to deal with psychiatric disabilities. Only four specialists were authorised for the whole of India, one each for the Northern, Eastern and Southern Commands and one for Western (Independent) District. The higher supervisory and advisory functions were carried out by the Assistant Directors of Medical Services (ADsMS) District, the DDsMS Command and the DMS in India at GHQ.

No special training courses in psychiatry were provided and medical officers with previous civil experience in psychiatry or those who underwent training in psychiatry while on study leave abroad were recognised as specialists in mental diseases. Such recognition was accorded by the DGIMS on the recommendation of the DMS in India in the case of IMS officers. The RAMC officers were recognised or graded by the War Office. Officers holding authorised specialist appointments were granted specialist pay at Rs. 100 per mensem.

Reports on soldiers considered ill were sent to the specialists in commands and Western (Independent) District. After considering these reports and often without seeing the patient they made their reports for the guidance of medical boards. Systematic treatment was impracticable and apart from a small ward in the British Military Hospital (BMH) in Bombay, the invalids were ordinarily accommodated in one or other of the BMHs in a prison-like apartment fitted with iron gates.

On the outbreak of war the specialists in medical diseases became occupied with other work and the psychiatric duties they had performed either ceased or were carried out by non-specialist officers. In a few centres there were RAMC officers with a little psychiatric experience and they were called in to deal with emergencies. The Superintendent of the European Mental Hospital at Ranchi, in particular, and the superintendents of one or two civil mental hospitals gave assistance to the army at that time. But there were no officers in the army devoting all their time to psychiatric duties.

APPOINTMENT OF CONSULTANT IN PSYCHOLOGICAL MEDICINE

Towards the end of 1941, the need for a consultant was felt owing to the rapid expansion of the Indian Army resulting in an increase in the number of hospital beds in India and the formation of large war hospitals in the Southern Command. Accordingly the appointment of a consultant in psychiatry for GHQ, India was created on 23 April

1942[1]. Brigadier E. A. Bennet was selected to fill this appointment. Till his arrival in India in October 1942, his work was carried out by the consultant physician, GHQ.

EXPANSION DURING THE WAR

It was also found necessary towards the middle of 1942, to determine the number of specialists required to provide an efficient specialist service both for peace and war hospitals in India. This review was the direct result of investigation carried out at the hopstials by the consultant physicians GHQ. The number of beds maintained for Indian and British troops in garrison hospitals in India had grown to more than twice the peace-time number, *i.e.*, to over 25,000 from about 11,000. Seven large war hospitals for the reception and treatment of casualties from overseas had been established between July and December 1940, at Karachi, Poona, Colaba, Deolali and Kirkee[2]. The volume of work for mental specialists had increased over and above the proportional increase due to the expansion of the army, because of the incidence of the anxiety state and other war neuroses. Accordingly two specialists in mental diseases were sanctioned for the war hospitals at Karachi and Kirkee and a pool of 10 specialists was created for peace hospitals in India with effect from 13 August 1942[3].

The posting of these officers was subject to the approval of GHQ and all posting orders were to make it clear that the appointment was within the number of sanctioned specialists. Officers posted to fill these appointments were eligible for the acting rank of major provided they were holding the status of recognised specialists[4].

Since his arrival in India in October 1942, the consultant psychiatrist had visited a large number of hospitals. At every centre visited, demands were made for the services of a psychiatrist. There were at this stage only six psychiatrists employed. A little later five more were accepted as specialists. This left only one vacancy in the authorised establishment of 12.

It was considered essential that in the hospitals for the treatment of British cases there should be at least one psychiatrist for each 50 beds and in the hospitals for Indian cases one for each 100 beds. This ratio of psychiatrists to hospital beds could not, however, meet the total psychiatric requirements as beds in a command were distributed over different areas and the total number of beds did not adequately represent the actual needs of the command.

Another important commitment for psychiatrists grew out of the needs of the selection boards. In the early part of the war the selection of officers for the army was made by provincial and central interviewing boards. It was generally agreed that this procedure required revision. After several months of careful preparation the first selection board in the India Command was opened at Dehra Dun on 15 February 1943. The board was based on the methods followed by the War Office selection

[1] F/2132/H(M).
[2-4] F/2195/H(M).

boards in the United Kingdom. But it differed in one respect; it was a combination of a War Office selection board and the old central interviewing board. This, although cumbersome, was a desirable transitional measure. The consultant psychiatrist acted as psychiatrist to the first three meetings of this board; he trained another psychiatrist who carried on until the middle of March 1943, when an expert team, trained in the technique of selection, arrived in India. This group, which included several psychiatrists, a psychologist and other officers, took over direction of the work at Dehra Dun. Building upon the original foundations, they ultimately developed selection as an effective—indeed indispensable—branch of the War Department's work. The proposal to start the first board met with no little opposition. This reluctance on the part of some senior (non-medical) officers soon gave place to active co-operation and selection was recognised as an undoubted success and of sufficient importance to warrant the formation of a separate directorate, the Directorate of Selection of Personnel, with the following staff:—

1 Director (brigadier)
1 Deputy director (colonel)
1 Adviser in psychiatry (lieut.-colonel)
1 Specialist in psychology (lieut.-colonel)
1 Specialist in psychiatry.
3 Deputy assistant adjutant generals (DAAGs) (1 for group testing control, 1 specialist in psychology).
7 Staff captains [5 may be WAC(I)].
5 Psychologists [civilian/Indian Commissioned Officers (ICOs)].
4 Psychiatrists (civilian/ICOs).
1 Officer supervisor and other clerical staff.

The above establishment was altered from time to time. The basic set up and the functions of the organisation remained more or less the same. The establishment sanctioned for a selection board was as follows:—

1 President—colonel or equivalent rank.
1 Deputy president—lieut.-colonel or equivalent rank.
2 Additional members—Indian civilians.
1 Specialist in psychiatry—major or equivalent rank.
1 Senior group testing officer—major or equivalent rank.
3 Group testing officers—captain or equivalent rank.
1 Psychological officer—captain or equivalent rank.
1 Staff captain i/c administration—captain or equivalent rank.
2 Testers—junior commanders in WAC(I)/sergeants and certain administrative staff—Indian or British other ranks.

The number of boards increased with the increase of commitments. There were five boards for the army one each at Rawalpindi,

Dehra Dun, Jubbulpore, Lonavla, Calcutta and Bangalore. Later a board was started for the Royal Indian Navy (RIN) at Lonavla. The Royal Indian Air Force (RIAF) board was located at Dehra Dun. The board for the WAC(I), composed entirely of women, was a mobile board in the beginning but was later stationed at Lonavla. The Medical Directorate provided the psychiatrists to the Directorate of Personnel Selection. The adviser in psychiatry supervised and directed the functions of the psychiatrists in the individual boards. Psychiatrists' work consisted of assessing the temperamental suitability, absence of psychotic or neurotic trends, prediction as regards trainability of the candidates and of clearing doubts arising in the selection boards as regards the above aspects.

FURTHER EXPANSION OF ESTABLISHMENT OF PSYCHIATRISTS

By early 1943, psychiatric work had greatly increased and was likely to increase still further. An investigation carried out by the consultant revealed the necessity of a larger establishment of psychiatrists for the following reasons :—

(i) Urgent need for treatment in order to avoid loss of manpower, and also to prevent a minor disability becoming a major one through absence of treatment on correct lines. When patients of this type did not receive early and correct treatment, they tended to pass from hospital to hospital occupying beds and gradually becoming chronic invalids. In many instances such cases had been evacuated ex-India quite unnecessarily.

(ii) The need for more out-patients clinics had become apparent. Many patients were being sent to hospitals by medical officers because they could not deal with them, and in the majority of centres there was no psychiatrist available to give advice. In the United Kingdom the bulk of psychiatric patients were seen as out-patients. The psychiatrist in his report to the medical officer advised on the treatment and handling of the case in the unit where this was possible. The aim was to prevent unnecessary admission to hospital. The adoption on a wide scale of such a procedure in India was advisable.

(iii) It was proposed to set up centres in Gouga Hospital, Secunderabad and at a wing of the European Mental Hospital, Ranchi, for the treatment of early cases and for the training of selected medical officers in the treatment of psychiatric cases. The combination of treatment and training necessarily involved a higher percentage of phychiatrists. Training of medical officers in psychiatry was considered essential as the supply of trained psychiatrists was very limited.

In view of the changing war situation it was impossible to say, in every case, where a psychiatrist was to be located. It was considered that the total number of psychiatrists sanctioned should constitute a pool under the control of the GHQ and postings made as and where required.

Taking all the above factors into consideration it was suggested that a pool of 33 psychiatrists, i.e., 12 already existing and 21 additional

should be sanctioned. As far as could be foreseen then they were to be located as follows[5] :—

TABLE I

Location of psychiatrists from the pool sanctioned on 7 May, 1943.

Armies/Command	Number of Psychiatrists
Southern Army	
Poona	6
Secunderabad	6
Bombay	1
Bangalore	1
Deolali	1
Central Command	
Lucknow	1
Bareilly	1
Lahore District	2
Dehra Dun and Chakrata	1
North-Western Army	
Rawalpindi	1
Karachi	3
Eastern Army	
Calcutta	2
Shillong	1
Other areas in Eastern Army	2
Ranchi	2
Ceylon Command	2
Total	33

In urging the need for the acceptance of this recommendation it was pointed out that the diagnosis and treatment of mental cases in the Army in India had been most unsatisfactory for lack of proper organisation due to the inadequacy of staff with special knowledge. It was intended, with the advice of the consultant psychiatrist, to rectify this state of affairs and thereby save considerable manpower. The investigation and recording of each mental case was a much longer and more tedious process than that of the average surgical or medical case. Even the policy of invaliding mental cases after a certain period, which led to much wastage of manpower, was to undergo a radical change. Thenceforth only genuine cases were to be invalided[6].

Accordingly a pool of 33 psychiatrists was sanctioned with effect from 7 May 1943, and placed at the disposal of the DMS in India for

utilisation according to actual requirements. Some of these psychiatrists were to be responsible for carrying out touring and investigation of patients requiring their expert services[7]. The establishment of a central pool was of considerable practical importance. The psychiatrists could then be attached to various formations, as necessity arose, without disturbing the establishment of the formations served by them. The value of this was proved later in the operational areas where flexibility of posting was essential.

At the time the above sanction was accorded it was anticipated that psychiatric work was likely to increase still further. This anticipation was fully realised by October 1943. The volume of clinical work had increased by that time to such an extent that 32 general duty officers with experience in psychiatry had to be posted to various centres to assist the specialists. The number of specialists and general duty officers actually employed in October 1943, as compared with October 1942, is indicated below :—

TABLE II

The number of specialists in psychiatry and general duty medical officers actually employed in October 1943 as compared with October 1942.

Armies/Commands	October 1942		October 1943	
	Specialists	General duty officers	Specialists	General duty officers
Southern Army and XXXIII Corps	1	1	14	12
Eastern Army (Eastern Command and Fourteenth Army)	1	...	7	10
Central Command ...	1	...	6	6
North-Western Army ...	2	...	2	3
Ceylon Command ...	...	1	1	1
Total	5	2	30	32

The expansion of base and garrison hospital beds and the proposed construction of a 1,000-bedded base psychiatric hospital (which had been approved in principle by the DMS) made it necessary to anticipate future needs. The number of beds in base and garrison hospitals had already risen to 70,300 and this figure was to be raised to 100,000. In addition, the needs of troops in forward areas, and more particularly in battle areas, were to be met.

A substantial wastage in manpower had taken place and was taking place day by day, owing to the failure of medical officers especially

[7] F/2489/H(M).

in forward areas, to diagnose psychiatric complaints, as these officers ordinarily had no knowledge of psychiatry. They had not been trained in this branch and were, therefore, incapable of distinguishing cases suitable for evacuation from those which should have remained with the unit. The result was that large numbers of soldiers were labelled 'NYD—mental', and evacuated with guards (which meant a further wastage of manpower). When there was delay in diagnosis and when cases were evacuated over long distances, they deteriorated; curable cases became incurable; hospital beds were crowded; and ultimately the patient became unfit for any form of military service, and had to be boarded out. With Indian troops, particularly a considerable number of those invalided applied for pensions—the last stage in a vicious circle which would never have been reached had a psychiatrist been present to assist the unit medical officer in the first instance. Lectures to medical officers on the recognition of psychiatric disabilities had been started and as psychiatrists became available these lectures were increased. Close contact with unit medical officers was thus essential.

The process of training inexperienced psychiatrists was necessarily slow. Intensive courses of lectures and demonstrations were organised for IAMC and RAMC officers at Secunderabad, Poona, Calcutta and other centres. But these courses did not prove altogether satisfactory. It was difficult to detach considerable numbers of trainee officers for special courses, as the army was short of medical officers. Moreover, such courses did not provide sufficient opportunities for clinical work. An exception was the course arranged at the European Mental Hospital, Ranchi, under the guidance of the Medical Superintendent. This lasted for three months and provided sound clinical opportunities for six specially selected officers. But consideration of time and expense made it difficult to repeat this course. After various experiments it was found that the most efficient training could be obtained by posting trainee officers to work with an experienced psychiatrist in a hospital or other centre for periods from nine months to a year. Where there were several psychiatrists—as in certain base areas—lectures and clinical discussion increased the value of the training. This worked well. It did not of course provide a full psychiatric training. But, as later experience proved, it enabled experienced psychiatrists to train carefully chosen medical officers successfully as army psychiatrists.

The onset of a disabling psychiatric malady could often be avoided by the proper handling of a situation by a combatant officer. It was found valuable to give lectures to combatant officers on the handling of men, on morale, and on kindred subjects. It was hoped to increase the range of such activities. Many combatant officers (not necessarily all juniors) believed that neurosis could be overcome by issuing orders and by stern measures. This was a dangerous fallacy, and had been shown, in this war, to result in an increase in neurosis and similar disorders.

Special duties fell on the psychiatrist in the event of active operations. Experience in North Africa, New Guinea and elsewhere, in this war, had proved that the treatment of psychiatric casualties in a forward area resulted in a saving of manpower. In modern warfare at

least 10 to 15 per cent. of the casualties were psychiatric in nature. If these cases were treated correctly and at once, by the psychiatrist, the majority of them could be returned to duty.

The practice of employing general duty officers on psychiatric duties, while inevitable owing to the number of patients, was open to objection. The practice was likely to lead to abuse by making it possible for general duty officers to be earmarked for psychiatric duties to the detriment of clinical work in medical wards. The consultants in medicine at the GHQ and in various armies and commands objected to this procedure, feeling with justification that if there was a need for more psychiatrists the establishment should be increased.

The orders authorising the existing establishment of 33 psychiatrists stipulated that these specialists would count against the existing establishment of medical officers for hospitals replacing general duty officers. This provision caused considerable difficulty. A psychiatrist although posted to a particular hospital and replacing a general duty officer there, was required to visit every hospital in the area and to go on tour to the neighbouring areas. The commanding officers of hospitals felt it to be unfair that their regular staff should be depleted because it was convenient to locate a psychiatrist at their hospitals. They pointed out that the psychiatrist was serving many hospitals ; they considered it unjust that one hospital should go short of an officer merely because a psychiatrist had to be posted to some unit as otherwise he would not get his pay. To meet this situation it was suggested that the pool of psychiatrists should be borne on a separate establishment. Such a step would obviate the necessity of locating a psychiatrist at a hospital or a formation and would not at the same time cause the withdrawal of a general duty officer from any unit or formation. The hospitals in the United Kingdom were faced with exactly the same problem and it was solved by the formation of a War Office psychiatric pool. The only way in which an efficient psychiatric service could be run was to have a single pool on whose strength would be borne all psychiatrists who were not posted to vacancies on the authorised establishment of the hospitals[8].

In view of the above facts sanction was accorded on 6 January 1944, for the formation of a pool of psychiatrists consisting of 70 medical officers. Officers in this pool could be posted within the India Command at the discretion of the DMS in India. The pool included 33 psychiatrists sanctioned in May 1943, which number was to be found from the existing number of general duty officers in medical units[9].

Till the beginning of 1944, mental patients were treated in separate wings or departments in a number of base general hospitals. These psychiatric centres were located as follows :—

Indian

150 beds at No. 6 IBGH(IT), Karachi.

200 beds at No. 131 IBGH(IT), Moradabad.

100 beds at No. 137 IBGH(IT), Secunderabad.

[8] F/2489/H(M). [9] A/2/57/H(M).

British

50	beds at No. 1 IBGH(BT), Karachi.
135	(expanded to 235) beds at No. 3 IBGH(BT), Poona.
120	beds at No. 126 IBGH(BT), Poona.
200	beds at No. 127 IBGH(BT), Secunderabad.
48	beds at No. 133 IBGH(BT), Bareilly.

The 120 beds at No. 126 IBGH (BT), Poona were for psychoneurotics only and the 48 beds at No. 133 IBGH (BT), Bareilly were for transit cases only.

This arrangement provided for one Indian and one British centre for psychotics at each base hospital group. The main Indian centre was at Moradabad. The main British centre was at Poona, so as to be near the port of embarkation to the United Kingdom. The small collecting centres were sited at various hospitals along the lines of evacuation and served as collecting stations for the patients prior to their evacuation to the base hospitals.

Towards the early part of 1944, the principle of a mental hospital to take both Indian and British psychotic and psychoneurotic patients had been accepted and plan for a hospital of 1,000 beds (300 Indian and 700 British) was under consideration. This hospital (No. 41 IBGH) was opened in the 'Hospital Town', Jalahali, Bangalore in July 1945. The hospital received all British psychiatric cases from ALFSEA and all Indian cases requiring prolonged treatment. With the opening of No. 41 IBGH, beds for psychiatric cases in No. 127 IBGH were reduced to 40.

The establishment for specialists in psychiatry and number of psychiatric centres were increased from time to time. Towards the beginning of 1945, there were in India, 42 psychiatric units employing over 80 psychiatrists providing some 1,700 beds for Indian and a similar number for British patients.

By August 1945, army psychiatrists had also succeeded in equipping centres at Alipore, Moradabad, Jalahali and Poona with electric convulsive therapy machines. It may be added that the first electric convulsive therapy appliance was brought to India by the consultant psychiatrist and was used in the Military Hospital, Karachi. Having used it for sometime in Karachi, it was transferred to Ranchi and later to Poona.

The increase in the number of psychiatrists was necessary because of the expansion of clinical work requiring their attention. There had also been an increase in the number of beds reserved for psychiatric patients, and in many instances special accommodation had been built. Out-patients clinics had also been enlarged, and in addition, there had been an increase in the number of lectures to medical and combatant officers on the preventive aspect of psychiatry.

By May 1944, it had become impossible for the consultant in psychiatry, India Command, to maintain close touch with the medical officers comprising the GHQ pool of psychiatrists. It was felt, as had

happened in medicine and surgery, that decentralisation would increase efficiency.

The policy of decentralisation necessitated the creation of the appointments of advisers in psychiatry in the Southern and Eastern Armies and Central Command with effect from 23 June 1944. The North-Western Army was to be looked after by the adviser in psychiatry, Central Command[10]. These were to act as advisers to the DDMS on all psychiatric matters within their respective Armies and Commands and were to co-ordinate and develop the work of specialists in psychiatry and to supervise the training of potential specialists and mental nursing orderlies.

Their responsibilities were heavy. Each one of them had to direct the work of eighteen to twenty-three psychiatrists. They were to maintain close liaison with heads of branches of the staff (who frequently sought their advice), with the Adjutant General's staff on questions of morale, selection and placing of personnel, with the Judge Advocate General's staff on disciplinary matters, with the staff of the Director of Army Welfare on problems of repatriation and welfare and with the staff of the Director of the Selection Personnel.

On account of their responsibility of advising on the innumerable questions which arose, not only with the DDMS army or command but with other staff officers, the rank of lieut.-colonel and additional pay of Rs. 250 per month was authorised for these appointments.

There was no new manpower commitment in the creation of these appointments as the officers appointed thereto were borne on the existing GHQ pool of psychiatrists. These appointments resulted in considerable progress in clinical work, in the training of potential psychiatrists, and in administration. Consultants and advisers had been (or were later) appointed in other specialities such as medicine, surgery, ophthalmology, etc[11].

A number of psychiatrists were appointed on an area basis within the commands and they were responsible for co-ordinating psychiatric work in their areas. A uniform system of psychiatric reports was adopted and every psychiatrist received detailed instructions upon the presentation of reports on patients and upon those awaiting court-martial[12].

MENTAL NURSING ORDERLIES (MNOs)

In the pre-war Indian Army the trade of MNOs was unknown. Amongst the personnel of the RAMC were many other ranks with experience of mental nursing in civil hospitals in the United Kingdom. They were used and their status was defined. By September 1943, 100 of these other ranks had been posted as MNOs to hospitals, and their number increased considerably as time wore on. Training courses

[10] F/2500/H(M).

[11] The duties of advisers are defined in Appendix A.

[12] The form of reports advised and notes upon them are reproduced in Appendix B.

were drawn up for others who possessed aptitude for the work of MNOs and these proved to be successful. These orderlies were all British. So far there were no Indian MNOs.

The old time system of military guards for Indian psychiatric patients was in full swing in the Indian Army till the later part of 1943. The guards were drawn from local units. The sepoys, equipped with rifles, made an odd picture in a hospital ward. This antiquated system was gradually given up and the guards were replaced by Indian MNOs. Five training centres were established and a course of training was drawn up[13]. This training course may seem rather ambitious, but it served as a guide to psychiatrists responsible for the training, and it led to uniformity in training in widely separated centres.

It is of interest and importance to record that the training of Indian MNOs was regarded as unwise by many senior medical officers with long experience in India. They informed the consultant psychiatrist that the type of mental disorder with which Indian soldiers were afflicted was totally different to that found in the United Kingdom and that these patients were extremely violent. This remarkable statement, often repeated, proved to be incorrect. Without doubt many of these patients were violent. But this seemed to be due to unwise management and an absence of proper nursing. It was believed that if these invalids were nursed as sick men, difficulties in controlling them would arise. And this proved to be correct. When trained MNOs were provided and guard dismissed, it was found that the patients presented few unexpected problems. But the introduction of a correct attitude towards the psychiatric patient was a slow process. It was not uncommon to find that hand-cuffs and even chains were used. This was easily understood when it is remembered that in several civil mental hospitals in India these methods of restraint were current practice. Mechanical restraint was indeed regarded as essential by senior medical officers—Indian and British—who had no experience of modern methods of nursing. One of the first official documents received by the consultant after his arrival in India asked for a supply of strait-jackets sufficient to equip every IMH in a certain command. It was surprising to learn that strait-jackets were in use and all were at once withdrawn. It will be seen, then, that the training of Indian MNOs was not without its problems.

ACCOMMODATION FOR PATIENTS

The provision of suitable accommodation for Indian and British psychiatric patients presented numerous difficulties. Tradition dies hard. In a number of hospitals it was found that orders were issued locally that mental patients must not escape ; and in consequence the wards in which they were placed were surrounded by barbed wire fences. Bit by bit the barbed wire, barred windows and locked doors disappeared. A building, known as the Standard Psychiatric Ward, was designed. This contained side rooms for patients requiring special treatment and

[13] See Appendix C.

one or two rooms for disturbed patients in addition to a central open ward. A feature of this standard ward was that it contained all the facilities of psychiatric hospital, in miniature, with accommodation for 25 patients. The ward was built as an addition to an existing military hospital and was part of the hospital. But the nursing and other arrangements were different to those in the medical and surgical wards. Where necessary two or more of these wards were built. In Lahore, for example, as part of the IMH, two standard wards were erected ; and in Moradabad, at the hospital for Indian patients, a unit for 200 patients was constructed by a series of standard wards. In base areas, such as Poona and Secunderabad, the standard ward was not used as the available buildings were adapted. The final step in the accommodation for psychiatric patients was the provision of a 1,000-bedded hospital at the 'Hospital Town' at Jalahali near Bangalore. This hospital was not opened till the summer of 1945, but thereafter it became the main base hospital for treatment till the close of hostilities and indeed for a considerable time afterwards.

PSYCHIATRY IN OPERATIONAL AREAS

It should be recorded here that the India Command and the Eleventh Army Group (which included the Fourteenth Army and later developed into ALFSEA), were under separate control, but that all the consultants at GHQ were also consultants to the Eleventh Army Group ; and—as in the India Command—they were all consultants to the Air Forces (Indian and British) as well as to the Army. The consultant psychiatrist continued to act in this dual capacity until November 1944, when a separate consultant psychiatrist was required for ALFSEA. This made possible close co-operation in psychiatric work between the forward areas and the hospital centres on the lines of communication and at the base. All psychiatrists working in the forward areas had experience of work elsewhere in India. The majority had received their initial army training in psychiatry at Poona, Ranchi or Calcutta. In consequence they knew the resources and the limitations of the hospitals in India. But of more importance perhaps was the fact that most of the psychiatrists knew and corresponded with one another. In this way the divisional and corps psychiatrists had no sense of remoteness, but worked as members of a team.

A mere record of facts would fail to give a clear picture of the tasks attempted, the difficulties experienced and the work accomplished. It is considered, therefore, that this section of the history will be made more 'alive'—hence of more value in the future—by reproducing here (Appendices D to G) some of the directives and reports issued at the time. These documents are numerous and a brief selection has been made. They include :—

(i) The notes made by the consultant psychiatrist GHQ in November 1943, and issued to psychiatrists in forward areas.

(ii) A memorandum on forward psychiatry, issued by the consultant psychiatrist in January 1944.

(iii) An extract from the report of the Kohima Battle up to 18 May 1944, issued from Medical Branch XXXIII Indian Corps.

(iv) The report (abbreviated) of a conference on psychiatry in forward areas, held at Calcutta in August 1944.

A survey of these four documents will give a picture of the arrangements made and the experience of those who were responsible for the treatment of patients in this active phase of the war at divisional and corps levels.

The appointment of psychiatrists to divisions in this theatre marks an advance in the history of army psychiatry. Divisional psychiatrists had been appointed in the Canadian and United States Forces ; but not with Indian and British divisions in Europe.

Owing to the variable nature of the fighting, improvised arrangements were often necessary ; and there was ample scope for initiative. The set up of forward psychiatry on paper was comparatively simple. Each corps psychiatrist, under the DDMS corps, formed a centre (50 to 100 beds) in a convenient medical unit, usually a CCS or a forward hospital, and each divisional psychiatrist formed an Exhaustion Centre to which were sent all patients considered by the RMO to be suffering from psychiatric symptoms. The majority of these, although presenting symptoms of a psychological rather than of a physical nature, were not psychiatric cases in the ordinary use of the term, but were suffering from a combination of factors of which, usually, the most prominent were physical and mental exhaustion. Fighting conditions on the Indo-Burma front, apart from hostile action, were severe. The climate particularly in monsoon conditions, the nature of the ground, shortage of food and water, fatigue and the lowered resistance following malaria and other illness, acted adversely even on the most stable. The fighting was intermittent in character. In quiet periods, particularly from sunset to dawn the presence of Japanese patrols made sleep difficult. During attacks on defended positions there was added the emotional strain of battle-danger, loss of comrades, incessant noise of gun and mortar fire, and the unrelenting demand on physical endurance.

CONCLUSION

The recorded experience of World War I upon the importance of training medical officers in elementary psychiatry had been forgotten. Psychiatry, therefore, had to start from scratch.

As the army grew in size and psychiatric disabilities became an urgent medical problem, the following steps were taken :—

(i) Experienced psychiatrists were posted as specialists.

(ii) Selected medical officers were trained as army psychiatrists.

(iii) General duty medical officers were given elementary training in the diagnosis and management of psychiatric illness.

(iv) Suitable other ranks were trained as MNOs.

It was noted that previous civil experience in psychiatry was not enough. Psychiatrists had to be trained to work in the frame-work of the army. It would have been a marked advantage if all psychiatrists could have had at least three months experience as general duty officers. In this way they would have understood better the details of army procedure.

Administrative experience showed the necessity for :—

(i) A consultant in psychiatry located at the GHQ.
(ii) Advisers attached to headquarters of each command.
(iii) A psychiatrist attached to each corps headquarters.
(iv) A psychiatrist attached to each divisional headquarters.

In addition, it would have been advantageous to have had a director of army psychiatry at the GHQ and an assistant director at each command and Army Headquarters. These officers would have been responsible for administration. It would not have been necessary for them to have been psychiatrists. A pool of psychiatrists with an establishment of its own, made it possible to post psychiatrists where they were most needed without disturbing the establishment of the hospitals or other units to which they were attached.

The provision of a standard psychiatric ward in each large hospital area was of great importance and contributed towards therapeutic and administrative efficiency.

The formation of a suitably designed psychiatric hospital in a base area came late (1945) in the India Command. Had such a hospital been available earlier it would have been invaluable as a treatment centre and as a training ground for junior psychiatrists and MNOs.

India Command was fortunate in having, from 1942 onwards, the co-operation of senior executive officers and of the DMS and DDsMS commands and armies. But it fell to psychiatrists to gain the co-operation of the senior executive officers. When this was obtained, it proved to be a vital link in raising and maintaining morale in training and in battle.

APPENDIX A

Duties of Consultants/Advisers in Psychiatry to Armies/Commands[14]

The duties of consultants/advisers to Armies/Commands are as follows :—

(i) To advise the DDMS of the Army/Command on professional matters pertaining to their speciality.

(ii) To devote the greatest possible part of their time to clinical matters and to tour and inspect with frequency and regularity.

(iii) To maintain liaison with the consultants/advisers at GHQ whose responsibility it is to co-ordinate clinical policy ; and to co-operate with them in the initiation and preparation of Medical Directorate, India, Technical Instructions. To attain uniformity no directives or memoranda bearing on general or special policy shall be issued without prior approval of GHQ.

(iv) To submit to GHQ monthly a statement giving information as to the medical and other units visited, and the volume and nature of the work taking place in them together with observations on clinical standards and other relevant matters.

(v) To submit to GHQ, quarterly, a report on all matters pertaining to their speciality suitable for use in the preparation of the medical history of the war.

(vi) To supervise and report on the work of specialists and of officers under professional training and to add comments to all applications for training, grading and specialists recognition in accordance with existing rules.

(vii) To encourage the professional training of officers, nurses and other ranks, in accordance with instructions issued by the DMS in India from time to time.

(viii) To supervise all official Army/Command research. Research will not be initiated without the approval of Research Advisory Committee, GHQ.

[14] Extracted from minutes of first meeting of advisers 16-17 September 1944.

APPENDIX B

The Psychiatric Report

The following notes, slightly modified, taken from *Technical Memorandum No.* 4 issued by the Directorate of Army Psychiatry, will be of value and should be carefully studied. Every report sent out by you is an important document and may have far-reaching effects not only on the individual but on the efficiency of the unit to which he (or she) belongs. A copy of all reports on disciplinary cases and on officers should be sent to Medical Directorate, GHQ. You should retain a copy of every report on your own files. Where a typist is not available carbon paper must be used. These notes were designed for the guidance of psychiatrists, reporting on British troops. Certain simplifications can well be introduced in rendering reports on Indian soldiers (e.g., regarding details of school, social and domestic career). The framework of the report should of course be the same for both.

THE FUNCTION OF THE REPORT

The work of an army psychiatrist may be completely vitiated by bad reports. Your effectiveness will depend on your reports and your effectiveness will be increased by attention to the following points—points which have given difficulty in the past.

It is of first importance to realise that the psychiatric report is advisory rather than clinical and also that it is written for the guidance of people who are not acquainted with psychiatric terminology. Your reports will be read by medical officers, medical board presidents, commanding officers, court-martial convening officers, commandants of detention barracks, ADsMS, and officer-in-charge-records. Accordingly, simplicity of language and avoidance of technical jargon are essential. Reports should be brief, yet lucid. In some cases more stress can be laid on the clinical aspect. For example, when admission to hospital is recommended, details of your clinical findings will be of value to the hospital psychiatrists.

THE FORM OF THE REPORT

In general, psychiatric reports will comprise the following :—

(i) *Heading :* ‘ Psychiatric Report—Confidential ’.

(ii) *To whom addressed :* In general, reports should be addressed to the medical officer of the patient’s unit. In some cases, especially headquarters of formations, the location must be omitted for security reasons. The person to whom your report is addressed is the person who should take action on it. If you send copies to anyone else, show at the foot of the report the destination of these copies, e.g., copy to ADMS 5th Division, copy to consultant in psychiatry.

(iii) *Patient's name, age, medical category, length of service and unit :* The importance of this information is obvious. The type of unit, man's age, and length of service will often have a direct bearing on the recommendation made. Mention the man's army trade, etc., if it is relevant.

(iv) *Date and place of examination, by whom referred, with what information, and for what reason.*

(v) *Complaints :* These should be given in the man's own words, if possible, and in some detail. Mention for example, severity, frequency, duration, date of onset, etc.

(vi) *Histroy :* The source of the information obtained must be stated. For example, ' He states that ....'. ' The unit medical officer reports that.........'. ' The general officer reports that.........'. ' AFB 178A records that.........' etc. A brief account should be given of the school record, where relevant, noting the type of school, the standard attained and at what age, and the top standard in the school ; employment record (length of time in job, change of job and for what reason, duration of employment, etc.) where relevant ; previous health and general ' adaptation '. Childhood symptoms should not be given in detail but should be alluded to by some such phrase as : ' He has shown numerous neurotic traits since childhood '. Confidential material should be avoided, for example say : ' There is considerable domestic and material stress ' rather than ' His wife is living with another man '. Do not elaborate on the past history or family history if it is irrelevant.

(vii) *Examination :* The results of examination should be couched in simple terms, avoiding psychopathological technicalities. The mental age in years should not be given as it is apt to be misunderstood by the laity. Specify any test you have used and give the score.

(viii) *Diagnosis :* This should be taken from the new Nomenclature of Diseases. Note here that depression is a psychotic diagnosis, and accordingly should generally not be used unless admission to military mental hospital is recommended.

(ix) *Recommendation :* This should in effect be the logical sequel to the previous information given. The case should be presented in such a way that it is made clear that what you are recommending is the best solution of the problem. You should briefly explain why this particular recommendation is necessary. The question of attributability or material aggravation should be mentioned if you recommend the patient's discharge since your opinion in this matter is of interest to the president of the medical board.

When making employment recommendations use general terms ; do not use precise terms such as ' sanitary orderly '. It is better to say ' simple routine tasks involving a minimum of responsibility '. Do not recommend a man to be sent on a course of instruction or posted to a particular employment unless he has the necessary ability and/or experience.

Do not pass opinions which should be given by another specialist, for example, 'because of his hernia, he should be re-categorised to B.1'. If admission to a hospital is recommended, send a copy of your report

direct to the hospital. State which hospital, and also mention that the patient should be accompanied by all relevant documents, in a sealed envelope and an (unarmed) escort where necessary.

The above form of report should be used in every case where the patient has been referred individually to the psychiatrist by the unit medical officer, hospital, etc.

REPORT IN DISCIPLINARY CASES

Where a patient is awaiting court-martial, you must always use the proforma given later; addressing it to the commanding officer and ensuring that the preamble at the head of the proforma is included. Remember that your function in these cases is to act as adviser to the convening officer. Section A of the proforma is the routine psychiatric report. It will be noted that the diagnosis has to be translated into non-medical language for the benefit of non-medical readers.

Section B deals with the question of fitness to plead. If your answers in this section indicate that the man will be found unfit to plead, then he is insane in the legal sense and will need to be recommended in Section E for admission to a military mental hospital. Section C is intended to assist the court to ascertain whether the man was legally insane at the time of the alleged offence.

In general, psychoneurotic states with such possible exceptions as authenticated hysterical fugues are not regarded as diseases of the mind which in this sense cause defect of reason, nor is mental defect so considered except in the grosser degrees.

Section D deals with the question of punishment, and here you are required to state any facts which might be considered in mitigation of the offence. If you consider there are mitigating circumstances, it is often convenient to answer the question, ' was the accused suffering at the time of the alleged offence from any illness which might have affected his behaviour ?' in the affirmative, and add, ' see attached report '. You should then attach a report giving details.

Section E deals with the medical disposal. If treatment is required you must state when.

By the adoption of an objective critical attitude, and by the careful wording of reports, disciplinary cases should not cause difficulty. In the past, most difficulties have arisen where psychiatric reports have contained contradictions.

PSYCHIATRISTS' REPORT

The attached report is intended as a guide for the commanding officer in considering disciplinary action where the question of the accused's fitness to plead sanity and responsibility has been raised. Where in the opinion of the psychiatrist a man is clearly fit to plead and clearly responsible for his actions at material times, a brief report to this effect may replace parts B and C of this report. If the accused is

remanded for court-martial this report must accompany the application for court-martial. The convening officer should submit the papers including this report to an officer of the Judge Advocate General's Branch before ordering trial.

Ref. No......................

To Officer Commanding.

Man's No.	Name.	Rank.	Age.	Service.

A. The above named who is charged with......................has been referred for psychiatric examination.

He complains that
He states that
On examination I noted that
In my opinion he is suffering from

B. *Unfitness to plead due to Insanity.*

(i) Is he able to understand the nature of proceedings at a court-martial ?

(ii) Is he able to object to any member of the court ?

(iii) Is he able to instruct his defending officer ?

(iv) Is he able to understand the details of the evidence ?

C. *Criminal responsibility.*

(i) Was he at the time of the alleged offence suffering from a defect of reason from disease of the mind ?

(ii) Did such defect of reason prevent him from knowing the nature and quality of the act he was doing ?

(iii) Or, if he did know, did he know what he was doing was wrong ?

D. *Evidence as to character.*

(i) Was the accused suffering at the time of the offence from any illness which might have affected his behaviour ?

(ii) Is punishment likely to diminish the chances that he will repeat this or similar offences ?

(iii) Is punishment likely to increase or diminish his efficiency as a soldier ?

E. *Medical disposal.*

(i) Is any treatment required immediately during detention or after release ?

(ii) Is any other action recommended ?

(iii) Any other relevant information.

APPENDIX C

Syllabus for Training of Mental Nursing Orderlies (Indian)[15]

SECTION A. THE MIND IN HEALTH

(i) *Psychology :* Definition ; mind and body relationships; instincts and reflexes ; three aspects of mind ; cognition (knowing) affection (feeling) and conation (striving) ; sensation ; perception ; skin sensations; visceral ; kinaesthetic ; apperception ; meaning ; ideation ; association of ideas, imagination, memory ; emotion ; passion ; mood, temperament ; volition ; attention ; complex.

(ii) The mind conscious and unconscious : repression ; projection ; introjection ; dreams.

(iii) Elementary anatomy and physiology of central nervous system ; brain ; spinal cord ; peripheral nerves.

SECTION B. THE MIND IN DISEASE

(i) *Psychopathology :* Definition ; classification ; psychoneurosis, psychosis, psychopathic states, mental deficiency.

(ii) *Signs and symptoms :—*

(A) *Physiological :*

(a) Sensory loss, excess, perversion ; pain.

(b) Motor, weakness, loss, inco-ordination; tremor; spasm; rigidity ; convulsion ; atrophy and hypertrophy.

(c) Reflexes.

(d) Condition of skin, muscles, bones, joints, circulatory, respiratory, alimentary, urinary, reproductive and endocrine systems.

(e) Stigmata of degeneration.

(f) Types of physique.

(B) *Psychological :*

(a) Sensation, analgesia, parasthesia. Changes in visceral sensation.

(b) Perception, illusions, hallucinations—types.

(c) Ideation, diminution, acceleration, obsessions.

(d) Judgement, delusions.,

(e) Memory, amnesia—types.

(f) Affection, apathy, excess, liability ; prevailing moods ; depression, euphoria.

[15] Issued as Appendix to GHQ letter No. 10044/DMS1(f) dated 4 November 1943.

(g) Volition and behaviour; diminution, overactivity; disorders of behaviour ; impulses, mannerisms, degradation.

(h) Speech ; mutism, disconnection incoherence.

(i) Combinations of the above terms, as in stupor, confusion, depression.

SECTION C. THE EXAMINATION AND NURSING OF MENTAL DISABILITY

(i) Attitude of MNOs to patient.

(ii) *Points in examination :* Attitude of patient towards examination ; personal hygiene ; general physical condition ; loss of weight, physical exhaustion. Heredity ; environment ; mental stress and conflict. Recent disease or wounds. Recent history of malaria, dysentery, typhus ; nutritional deficiency ; heat-exhaustion ; alcoholism ; drug addiction.

(iii) Management according to clinical condition, e.g., elated, excited, noisy, destructive, violent, suspicious, resistive, confused, stuporose, depressed.

(iv) Observation of fits. Differential diagnosis. Malingering.

(v) Methods in treatment ; simple psychotherapy (persuasion, suggestion, encouragement), sedatives ; diversional therapy. MNO's duties in ; narcoanalysis, continuous narcosis, convulsant therapy, hydrotherapy, pyrotherapy.

(vi) Feeding of patients ; oral, nasal and rectal feeding.

(vii) Emergencies : attempted suicide, artificial respiration, use of stomach tube ; first aid (e.g. arrest of haemorrhage).

SECTION D. GENERAL DUTIES OF MNOS

(i) Reception of new patient ; inspection for bruises ; abrasions, blisters, and other signs of injury. Searching of patients for dangerous objects.

(ii) Ward discipline—general principles.

(iii) Bathing of patients and rules for baths.

(iv) Bedding and clothing inspection, restrictions and precautions.

(v) Observation of patients at night.

(vi) Arrangements for actively suicidal patients.

(vii) Use of mechanical restraint.

(viii) Observation and reports ; sleep, food, weight, bowels and bladder, behaviour and habits. Sleep and weight charts. Medicine (sedative) book.

(ix) Duties of MNOs in connection with transfer, discharge or death of patient. Army forms used in psychiatric ward.

APPENDIX D.

Psychiatry in Forward Areas[16]

INTRODUCTORY

Experience gained in this war—in France, North Africa, Sicily, Italy, New Guinea and the India Command—has shown that psychiatric casualties fall into two main groups : those suitable for immediate treatment in a forward area and those for evacuation to base hospitals.

The following notes are concerned mainly with the former group. They are intended for the guidance of psychiatrists posted to forward areas.

INCIDENCE OF CASUALTIES

Approximately 10 to 15 per cent. of all casualties will present psychiatric symptoms. This figure has been more than doubled in certain engagements. With prompt treatment a high percentage can be returned to full duty. The actual percentage has varied a great deal (from 50 to 80 per cent.). Local conditions of terrain, degree of hostile resistance, weather, and other factors naturally play a part. On the whole the percentage of those returned to full duty has tended to fall, the explanation given in North Africa and Sicily for this is that RMOs are becoming much more psychiatrically minded and handle their cases with more skill so that only severe cases are referred to the psychiatrist working close to the front. Experience in this work is comparatively recent and too much emphasis need not be placed on figures.

LOCATION OF PSYCHIATRIST IN FORWARD AREA

This will depend on the nature of the engagement, disposition of troops and other conditions. But, in general, experience shows that he ought not to be further back than the CCS or MDS. At this level it has been possible to group the psychiatric casualties, give suitable treatment (see later), and make a decision regarding the patient's disposal—is he fit to return to the line, or must he be evacuated ?

In the India Command a psychiatric team has been placed at the disposal of the DDMS corps. This team is composed of a specialist in psychiatry and three general duty officers trained in psychiatry. One or more of these general duty officers may be replaced by a graded psychiatrist. The policy adopted in North Africa with British and American troops was somewhat different. But conditions here, especially as regards distances, and the nature of the ground are not comparable with any other field of operations.

[16] From the Consultant Psychiatrist, India Command, 16 November 1943.

Each psychiatric team has been (or will be) provided with a supply of sedatives, syringes, etc., so that they can operate, if need be, as a mobile unit working with any formation (CCS, MDS, etc.) as need arises.

PREVENTIVE WORK

The closest co-operation with RMOs and medical officers in forward formations is essential. These officers, (and not least junior IAMC officers) have little or no knowledge of psychiatry. They are, therefore, liable to label patients 'NYD-mental' and get rid of them. They must, therefore, be given every assistance. An excellent plan is to have the medical officer present when a patient is examined. The psychiatrist has much to learn from medical officers. The RMO particularly knows the soldiers who are repeatedly sick, and often he can form a good judgement about the stability of officers in his unit. Consequently, his assistance in eliminating the potential psychiatric casualty, before active operations begin, can be of value. Early diagnosis of the psychiatric weakling is of great importance. When such men are not known and disposed of before a unit is engaged in active operations, unfortunate results occur. They are a source of irritation before battle and later become an increasing responsibility owing to their inefficiency, and liability to breakdown. Their presence will undoubtedly have an adverse effect on general morale. It must be made clear that in assessing these cases, the individual army record should be placed beside the clinical findings. The value of contact with executive officers and senior NCOs as well as with medical officers is great.

In this group will be found :—

(i) Chronic psychoneurotics
(ii) The dull and backward
(iii) Psychopaths
(iv) Psychotics
(v) Misfits

These terms may be used as a guide to the RMO. The meaning of the terms and recognition of the symptoms, each group is likely to show, should be made clear in conversation or in lectures to medical officers. Malingerers, and those who exaggerate their symptoms, are a frequent cause of perplexity to medical officers. The true malingerer may be rare, but he does exist. Emphasis should, therefore, be laid on the importance of the previous history (civil and military) and on the history of the illness. The onset and development of psychiatric illness is known to psychiatrists. This knowledge should be passed on, and it is necessary to help medical officers in this matter. Particular care is required when dealing with IORs diagnosed as suffering from 'fits'.

Selection Work : This important branch of preventive psychiatry cannot always be efficiently handled by the psychiatrist alone. He can deal with the individual soldier. But when a large group is thought to require selective testing application must be made to the consultant in

psychiatry, GHQ who will arrange with the Director, Selection of Personnel for a team of testers to be sent. Each psychiatrist must bear this in mind and take action before units are engaged in active operations.

SIGNS OF INCIPIENT BREAKDOWN

The development of symptoms may be sudden and dramatic; but, in a large percentage of cases closer investigation will reveal the final breakdown merely as the end stage in a series of changes which may have been developing over days, weeks, or even months.

The symptoms vary with the individual and with the type of syndrome in question, but they tend to conform to certain easily recognisable types.

If a soldier in the groups mentioned under 'Preventive Work' has not previously been diagnosed, his breakdown may have an apparently sudden onset. But officers and men of good personality subject to strain with exposure to difficult climatic conditions, hostile action, lack of sleep and other contingencies, may breakdown. Under such conditions the onset may be sudden or gradual. In nearly every case, however, prodromal symptoms will be present and medical officers should be instructed to be on the look out for such symptoms. Amongst the commonest signs of distress will be :

(i) An alteration in temperament and personality. The quiet, self-effacing, retiring individual becomes garrulous and vivacious, or conversely the good humoured and sociable man becomes morose, sullen and solitary.

(ii) Emotional instability is often marked—sudden outbursts of weeping for no apparent cause, or sudden displays of aggressiveness or of violence. Disciplinary offences, of a trivial type, may occur in a person of previously exemplary character. There is often a gradual deterioration in the standard of work and efficiency—an inability to concentrate, of which the soldier may be acutely conscious; and this intensifies his sense of restlessness and depression.

(iii) A general feeling of tenseness is experienced—the individual is restless and 'jumpy', anxious, irritable and apprehensive, unduly startled by sudden noise. Insomnia may be present with, or without, disturbing dreams of an anxiety type. Headaches and a wide variety of psychosomatic symptoms may be in evidence. Gradual but progressive loss of weight is often associated with these symptoms and may provide an early and important sign of approaching breakdown. Increased consumption of tobacco and alcohol may be observed.

In every case where mental symptoms make their appearance, either as prodromal signs or in actual breakdown, the possibility of physical factors should be investigated. Heat-exhaustion, infection (malaria, dysentery, dengue, etc.) and infestations, are not infrequently accompanied by psychological disturbances which may vary from slight irritability to complete mental confusion or transient psychotic reactions.

TYPES OF PSYCHIATRIC CASUALTIES

Any of the various psychiatric syndromes may make its first overt appearance during battle. It will be found that the largest proportion (60 or 70 per cent.) present acute anxiety reactions. Hysterical reactions are common amongst Indian troops and occur next in frequency to anxiety states[17]. Other forms of neurosis or of psychosis may occur, but are numerically of less importance.

(i) *Physical Exhaustion :* A state of abnormal fatigue is found, with mental and physical lassitude, apathy or depression, often with various associated aches and pains of a generalised type, resulting from excessive mental and physical stress. The onset is usually less dramatic than in the conditions detailed below ; and although anxiety, with or without its physical concomitants, may be marked, the more pronounced behaviour disorders or conversion phenomena are not found.

(ii) *Simple Terror State :* An acute condition of sudden onset, developing under conditions of danger and often affecting men of excellent previous personalities.

The symptoms vary and may take the form of a positive or negative reaction to the precipitating situation : the individual may shout and scream, run about in an aimless fashion, and show the typical signs of acute panic ; or he may display all the signs of collapse and appear dazed, confused or semi-stuporose.

The condition is transient, the precipitating factors usually obvious, and the response to suitable treatment rapid.

Some authorities declare that any differentiation between terror and anxiety states is purely artificial, but retention of the term seems justifiable for distinguishing cases which can be treated in the line.

(iii) *Anxiety State :* In the acute anxiety state, developing during battle, disorders of behaviour are often prominent—acute panic may develop resembling the more simple terror state, but not responding so readily to treatment, and characterised at times by episodes of extreme aggressiveness or even violence.

Other types of anxiety state may be less spectacular but equally disabling, with gross generalised tremors, racing pulse, sweating, confusion and extreme restlessness and anxiety. Semi-stuporose states are common.

Psychosomatic symptoms may be prominent, either in association with the above, or in more isolated form—as, for example, the palpitation, giddiness, dyspnoea and precordial pain typical of the effort syndrome.

It is important to bear in mind the possibility that symptoms, superficially suggestive of an acute terror or anxiety state, may in fact be of organic origin and the result of concussion or head injury.

[17] Indian troops showed hysterical reactions in a preponderate degree in the early years of war. In the later war years, anxiety reactions were seen in a fairly large number.

(iv) *Hysterical Reactions :* Dissociations of various types, e.g., amnesias or fugues—are the commonest types of hysterical reaction encountered, and they often present considerable difficulty in assessment and diagnosis. Conversion symptoms such as paresis, blindness, deafness or mutism are fairly common. Collapse, or hysterical convulsions, may also occur.

(v) *Depression :* This is a common symptom and may dominate the picture or form the principal symptom of a more general reaction, e.g., of an anxiety state.

Depression, with retardation, insomnia, and ideas of guilt and self depreciation, is common in older men. It has been found in NCOs of good previous personality, but of the worrying and over-conscientious type. The differential diagnosis between neurosis and psychosis may at times be difficult.

(vi) *Obsessional Neurosis :* This condition is comparatively infrequent, although mild obsessions and phobias may of course be present as symptoms of other neuroses. The main importance of recognising the condition lies in an appreciation of the unfavourable prognosis and of the necessity for evacuation to the base when treatment becomes necessary.

(vii) *Psychosis :* It is not impossible that the symptoms of a psychosis may first display themselves in battle, although this is uncommon. Symptoms suggestive of a psychotic reaction, and often diagnosed erroneously as such, occur in the severe types of 'battle' neurosis. Regressive behaviour, stupor, depression, etc., in a psychiatric casualty should not be regarded as psychotic in the first instance.

TREATMENT.

Prodromal Stage : An impending breakdown can often be averted by the medical officer applying such measures as :

(i) Simple psychotherapy which here consists merely in listening quietly to the man's troubles, giving an explanation of their natural causes and a firm reassurance that they are neither shameful nor signs of approaching insanity (a very prevalent fear). The explanation that fear is a normal physiological reaction to stress, that no man need be ashamed of it, but only of being mastered by it, is helpful to many.

(ii) Ensuring adequate rest by sedatives (bromide grains 30 or luminal grains $1\frac{1}{2}$ to 3 t.d.s. for 3 days with increased dose where indicated to produce a good sleep.)

(iii) Verifying that the soldier is consuming his full rations and taking adequate fluids.

(iv) Changing duty temporarily to light, but useful work.

Many will recover in a few days. A complete examination must be carried out to avoid any suggestion of evacuation.

Simple Terror State : Firm, quiet, assured and unhurried handling has a marked effect. Blustering tactics will increase the severity of

the symptoms. A sedative and a hot drink should be given, and the patient told to lie down. If circumstances permit, sufficient sedative should be given to produce three or four hours sleep. The majority will be able to return to full duty.

Evacuation of Patients : Indiscriminate evacuation has serious effects on morale and on manpower and is to be avoided. The further a soldier gets from his unit, the less chance is there of getting back to duty. But certain types of casualty must be evacuated, and evacuated with all speed. The only real guide is experience. Conditions of acute anxiety, gross hysteria and physical exhaustion should be sent to the CCS or to whatever centre has been arranged by the psychiatrist.

The responsibility of the RMO in cases requiring evacuation from the line consists only in evacuating them quickly and under adequate sedatives. Experience has shown that the sooner a sedative can be given the better is the result likely to be. The choice of drugs and the dose administered, will depend to some extent on what drug is readily available ; whether the patient is an ambulant or stretcher case ; and on the distance to be covered. If a patient has to walk a considerable distance, he may be given a relatively small amount of sedative, e.g., morphia grain $\frac{1}{4}$ or hyoscine grain 1/100 subcutaneously, or medinal (barbitone soluble) grains 10. or paraldehyde 2 drachms orally. If he has to be carried (e.g. stuporose, collapsed, etc.) he can be 'put under' with a larger dose and will benefit as a result. In the latter case a quick acting drug is more suitable, e.g., phenobarbitone soluble grains 3 injected intramuscularly. (This may be available in ampoule form, or may be prepared without the use of heat, otherwise toxic decomposition products are formed). It is of the utmost importance in every case to record fully, on the field medical card, the drug or drugs employed, and the exact dosage administered.

A psychiatric casualty must not be labelled 'shell shock' 'NYD' or 'mental NYD'. The term 'exhaustion' which implies recovery, will be employed. Whenever possible a brief statement as to the patient's previous personality, and the circumstances of his breakdown should be appended. This will be of great assistance to the psychiatrist assessing the prognosis and in deciding the type of treatment to be employed. A brief but useful method is to label the previously valuable soldier as 'good personality'.

These notes do not touch on every problem that will arise in forward area work. Much is left to the initiative and enterprise of the psychiatrist. But one thing is certain—that the psychiatrist, working in close touch with the RMO, can make an important contribution towards saving manpower and towards maintaining morale at a high level.

APPENDIX E

Memorandum on Forward Psychiatry[18]

The general policy, in forward psychiatry, is based on the need for conserving manpower. Experience in North Africa and in Italy indicates that serious wastage occurs as the direct result of unnecessary evacuation. To combat the tendency of sending every psychiatric patient to hospital, which is often marked amongst inexperienced RMOs, it is necessary to provide facilities for early diagnosis and appropriate treatment. It is most necessary in forward areas. The functions of a 'front-line' psychiatrist may be summarised as follows : to give instruction and advice to RMOs, concerning psychiatric conditions likely to arise in the field, and to supervise the sorting out of casualties and administer treatment as expeditiously as possible with the aim of returning the highest possible number to duty. In addition, invaluable work may be done by contact with combatant officers to discuss problems of morale and man-management. While the good officer may be fully aware of the subtleties underlying morale, in many instances the psychiatrist's advice may help (and indeed has helped) to clear up problems which are lowering unit and individual efficiency. The recognition and removal of misfits and psychiatric weaklings, before engaging in active operations is of supreme importance. If this is carried out effectively subsequent pyschiatric casualties will be low and morale will benefit in consequence.

In order that this policy may be implemented in the Eleventh Army Group, psychiatric teams with the necessary medical equipment in special panniers, were posted to various areas, as follows :—

XXXIII Corps.	2nd Division.
	36th Division.
	25th Division.

A verbal request was made by the DDMS XXXIII Corps that the services of psychiatrists should be retained with the divisions as they were familiar with RMOs and combatant officers ; and the consultant psychiatrist accordingly asked for them to be posted to divisional headquarters.

IV Corps.	1	Specialist in psychiatry (corps psychiatrist).
	1	Graded psychiatrist.
	2	General duty officers trained for psychiatric duties.
XV Corps.	1	Specialist in psychiatry (corps psychiatrist).
	3	General duty officers trained for psychiatric duties.

In addition to the above, one psychiatrist was posted to Headquarters XV Corps with the suggestion that he should be employed at either No. 68 IGH (C) or No. 72 IGH (C) and one was posted to Gauhati and another to No. 17 BGH at Dacca.

The work which had already been accomplished, evoked favourable comments from general officers and from the DDsMS.

[18] By Consultant Psychiatrist—January 1944.

There are several points worth mentioning in connection with the activities of psychiatric teams :—

(i) The psychiatric teams are at the disposal of the DDMS corps. Owing to the fact that they are borne on the pool of psychiatrists, they can be placed in any unit as circumstances require, without disturbing existing establishments.

(ii) The senior officer in the psychiatric team (corps psychiatrist) should be in charge of the team and initiate necessary action, with the approval of DDMS corps, regarding the location of each member of the team.

(iii) In general, at least one of the psychiatrists should be located sufficiently forward to be in direct contact with RMOs.

Treatment of casualties evacuated from the line will be commenced at a rest centre situated at ADS or MDS level, where approximately 20 beds should be provided. A considerable number should be able to return to duty after treatment lasting from some hours to a few days.

Cases requiring further treatment—say up to 14 days—will be evacuated to an advanced psychiatric centre where a further sorting out will take place. This centre will usually be located at the nearest convenient general hospital, but in some instances at a CCS. Casualties reaching this stage will either be returned to full duty in the line, or down-graded as fit for modified duty (e.g. lines of communication area) or evacuated to base hospitals.

Accommodation was provided *en route* for cases being evacuated to base. The provision of a 24-bedded standard designs ward was already authorised at No. 66 IGH(C), No. 68 IGH(C), No. 62 IGH(C), No. 63 IGH(C), No. 75 IGH(C) and at IMH, Alipore.

All psychiatric casualties should be labelled ' exhaustion ' in the first instance, i.e., when evacuated from RAP to the 'rest centre'. This term implies recovery. The term ' NYD-mental ' should be forbidden. More precise diagnosis can be made by the psychiatrist. This is in accordance with the policy adopted by GHQ.

MNOs : In order that a nucleus of trained staff may be at the disposal of the psychiatrist, two MNOs were posted to certain hospitals in the XV and IV Corps area, respectively, and it was urged that these MNOs should be employed under the orders of the psychiatrists.

To ensure the efficient working of this scheme for forward psychiatry, there are certain additional requirements which should be met :—

(i) *Transport :* It is impossible to forecast, days ahead, the demands on pool transport ; and corps psychiatrists and other members of the teams experienced much difficulty, and consequent waste of time, on this account. Neurosurgical units were supplied with the necessary vehicles, and the needs of psychiatric teams should likewise receive attention.

(ii) *Clerical Assistance :* A great deal of time was spent by the psychiatrists in routine clerical work. In some instances this involved the completion of numerous army forms. This is a work which should be done by a clerk. It is a waste of manpower to use a psychiatrist for such duties.

APPENDIX F

Extract from Report of the Kohima Battle up to 18 May 1944. Medical Branch XXXIII Indian Corps

TREATMENT OF PSYCHOLOGICAL CASUALTIES

A forward treatment centre[19] set up at milestone 28 (Priphema) was worth its weight in gold. A graded psychiatrist attached to the 2nd Division ran this centre. It was provided with 30 beds (*charpoys*), sheets and pillows, all necessary drugs and equipment, bath facilities and a good cook. A wireless set and gramophone were important items of equipment. It was lucky that a MNO from a field ambulance was available. Cases ranging from acute terror state to simple exhaustion were treated here and the results had been surprisingly encouraging. Nearly 50 per cent. of those treated were returned to their units in an average of 4 to 5 days and only one of these returned—the result of an unfortunate bombing immediately after arrival with his unit.

The centre was administratively tacked on to No. 76 Indian Staging Section—not an entirely satisfactory arrangement, but it worked.

Evacuations from this centre should be to a CCS (or hospital) with a special wing for reception of up to 75 psychological casualties.

[19] Suggestions as to how a 'psychiatric forward treatment centre' should be made up are given in Appendix H.

APPENDIX G

Report of A Conference on Psychiatry in Forward Areas

(held at Calcutta August 8-10, 1944)

Introductory remarks by :

(i) Brigadier E. A. Bennet, MC

(ii) Major-General N. Cantlie, MC

(i) Brigadier Bennet made the following observations :

(a) All psychiatrists in the India Command, and the Fourteenth Army, in the Eleventh Army Group, were carried on the GHQ pool of psychiatrists. Consequently, it was possible to post psychiatrists to corps and divisional headquarters, and to certain hospitals, CCSs and field ambulances, without disturbing the establishment of these formations. This arrangement worked smoothly. The psychiatrists were mobile, and could be attached, where most needed, at the discretion of the DDMS or ADMS concerned.

(b) The psychiatrists worked in a combat zone which lay in hilly and thickly wooded jungle country, where communications were difficult. Units in the same corps, or division, frequently fought far apart. The lines of communication within the corps area were long, and evacuation slow and hazardous. For three months the IV Corps, centred on Imphal, was dependent on communication by air for supplies and evacuation of casualties. Smaller formations, within this corps, were in many instances based on 'box' or perimeter camps. A similar 'box' was formed in the area occupied by the 7th Indian Division in the Arakan. To cater for the psychiatric needs of troops in the Fourteenth Army presented a problem very different to any experienced in Middle East Forces, North Africa, Italy or France. The climate—extreme heat and later, monsoon conditions—was an added complication. Nevertheless the work went on, and the results—particularly in saving manpower by treating patients on the spot, rather than by evacuation—were considered to be satisfactory.

(c) The appointment of divisional psychiatrists proved a success in action. In other theatres of war there were no divisional psychiatrists (except with Canadian and United States forces). The divisional psychiatrist was welcomed and accepted as 'a member of the family'. In one division indeed, there was a request from the division commander for a second divisional psychiatrist.

(d) Favourable comments on forward psychiatric work have been made by the DDMS, Fourteenth Army and by the DDsMS of IV, XV and XXXIII Corps.

The DDMS, Fourteenth Army writes :—

"Your specialists have been, and are, doing invaluable work, especially in the forward areas, and all formation commanders are most enthusiastic. I trust that you will be able to enlarge the scope, especially as regards Indian troops. It would, I feel, be an advantage to have psychiatrists attached to training divisions and brigades in India, if this is practical".

(e) The DDMS, XXXIII Corps, in making suggestions for future work, reported that the psychiatric work carried out during the Kohima Battle proved most valuable. He referred especially to the forward treatment centre which he described as 'worth its weight in gold'. The DDMS, XV Corps, stated that of the two outstanding medical achievements during the recent fighting on the Arakan, one was the work of the corps psychiatric team. He added, that the corps commander had expressed the highest appreciation of what had been done, and particularly that facilities had been provided, so far forward, for these patients to be treated. He noted also that many had been returned to duty who would otherwise have been evacuated. It is satisfactory to record appreciation of psychiatric work from the 'G', as well as from the strictly medical angle.

(f) Conditions varied from corps to corps and from division to division. The fighting was fluid, especially in the northern area, and there were numerous withdrawals with subsequent advances. What worked in one area did not necessarily work in another. A description is given later of arrangements which did in fact work and proposals for future operations are made.

(ii) Major-General Cantlie, said that he was very pleased indeed to open this conference of psychiatrists. He complimented Brigadier E. A. Bennet on the comprehensive organisation which had been built up in the short time of less than two years. Of special importance was the scheme for the forward treatment of psychiatric casualties, of an acute form, occurring during the course of battle. By tackling these cases at an early stage in their illness before it had the chance of developing into a resistant and chronic structure, psychiatrists had made a valuable contribution towards the saving of manpower and towards lightening the burden of hospitals in the rear. From being a bit of a sceptic to start with, and with the idea in the background that psychiatry was a bit of a ramp, he had been converted, by actual experience, into full believer.

A word of warning was necessary to psychiatrists, the majority of whom had come straight from civilian practice to undertake psychiatric duties in the army. In civilian practice they were dealing with patients for whom, in the main, illness was a disadvantage because of the consequent loss of earning power or opportunities for advancement in their careers. In the army conditions of life for the individual were very different. In war time the army was comprised largely of men conscripted from civilian life. Collectively they were imbued with the wish that all their energies should be directed towards attaining final victory over the hostile force. In their ranks nevertheless, were men who by reason of deficiency or abnormality in their make-up, were incapable of fitting smoothly as cogs in the military machine. There were also, without doubt, those who realised that the proffering of some degree of unsuitability would perhaps reduce their chances of being selected for certain dangerous duties, and who, therefore exaggerated, or made little effort to overcome, quite normal fear reactions to the threat of danger. Some could even be considered guilty of not trying to overcome the slight stress inevitable in the switchover from a life of their own

choosing, under peace-time conditions, to the more strictly directed life of a soldier.

The need for army experience in dealing with the soldiers was emphasised. Psychiatrists must be on the alert for the malingerer, and it was important that the report of the soldiers' commanding officer and company officer should be obtained as well as that of the RMO.

It was in distinguishing these two very broad groups (the defective or abnormal and the malingerer) that a great responsibility rested with the psychiatrist. To equip himself for this task he should have an intimate knowledge of the soldier and how he lived during his training period and under conditions of active service.

When a psychiatrist was first posted to his corps in North Africa, General Cantlie told him that he was the most unwanted man in the corps. The general officer commanding was afraid that, since he had a psychiatrist, discipline in the corps would be ruined. A man who was under arrest for some breach of discipline it was thought, had only to see psychiatrist, tell a tale of his mother being frightened before he was born, or some such plausible tale, and he would be let off any punishment. The general officer commanding said the psychiatrist would be judged by results, and if the results, as regards discipline, were poor, the psychiatrist would get the sack. It can now be said that these early fears were groundless. The psychiatrist proved his worth.

The first essential was that the psychiatrist must go into action and see the stress and strain of battle. He must see troops tired from lack of sleep, hungry and thirsty, deafened by the noise of battle ; and he must experience all this from the RAP level and forward of it. It is essential that the psychiatrist should have actual experience of the field of battle. Psychiatry at the divisional level in battle was relatively simple, and on the whole the results were very good indeed.

Speaking broadly, cases fell into three groups. Firstly those acute conditions, wherein fatigue, fear, lack of sufficient sleep, water and food, had overcome the normal resilience of the human mind. These cases were classed under the label ' exhaustion '. In this group the psychiatrist had to distinguish men in whom there was a conscious wish not to return to the battle-front. It was looking for trouble to let such cases slip through to the rear. The remainder responded quickly to rest, sleep, food and reassurance.

Secondly, a group consisting of dullards and those of an inherent mental instability. Often men of this type made a good endeavour to carry on in the battle, but their native mental equipment was just not good enough for the job in hand. Psychiatrists could do much good work here in assessing what assets such men did possess, and in making recommendations for their employment in some job within their capacity.

Thirdly, there was the group of truly insane cases, the genesis of whose illness was constitutional and related, only coincidentally, to the fighting in which they had been participating. With these, only the question of disposal arose.

The role of the psychiatrist in the field, was that of adviser to the ADMS or DDMS. Every administrative decision on psychiatric matters had to be made by the ADMS or DDMS. He might seek the psychiatrist's advice, but must make his own final decision in the light of all relevant circumstances.

It was important to know the medical officers of the units under one's care if one were to evaluate correctly the information received from them. An instance was quoted of a medical officer from whom numerous cases had been received and whose interest in psychiatry was marked—too marked—and who later was himself evacuated as a psychiatric casualty.

The RMO who dabbles in psychiatry on the wrong lines, and without adequate experience, is a danger to a unit, and should be removed.

The future will lie more, he hoped, in preventing breakdown under the hideous din of war. The psychiatrist should give advice to commanders on various aspects of battle, such as the importance of overcoming administrative difficulties, so that men went into battle well fed, and all similar matters bearing on unit morale. Instructions to RMOs on the correct use of sedatives and stimulants was also a responsibility of the psychiatrist.

Psychiatrist in forward areas working along these lines could make an important contribution to the prophylaxis of psychiatric illnesses.

PSYCHIATRY AT DIVISIONAL LEVEL

Full reports follow of psychiatric work in (1) The 2nd British Division, and (2) 20th Indian Division. These divisions fought under very different conditions of terrain and tactical disposition. While the general plan of divisional psychiatry was common to both, each divisional psychiatrist had unique problems. Shorter notes on the work in (3) 25th Indian Division, (4) 26th Indian Division and (5) 36th Division, are added as they contain additional information.

(1) *2nd Division :* This division attacked Kohima. The fighting was severe, movement rapid, the weather appalling, and casualties heavy. The division had undergone training for another role, and consequently on arrival at Kohima the psychiatric organisation had to be improvised to meet an unexpected situation.

It was not clear to begin with where a psychiatric centre might function most efficiently. The psychiatrist began work at the MDS of a field ambulance located on the outskirts of Kohima, and patients were received direct from the RAP. The noise of battle was so great, however, that it was impossible for the men to rest and relax, and the dose of sedative to give adequate sleep had to be increased beyond what was desirable. Accommodation at the MDS was limited, and there was difficulty in holding cases for an adequate time. The attempt to function there was, therefore, abandoned. With the active help of the DDMS corps, and ADMS division, a psychiatric centre was set up 18 miles behind the actual front-line, at milestone 38, on the Manipur Road.

This centre proved to be ideal. It was in a corrugated iron shed capable of holding 30 to 40 *charpoys* (string beds). In one of the large rooms a corner was screened off to form a ward, of 5 beds, for officers. A small room was used as a reception and consulting room, and the nursing staff was accommodated in another small room. Outside were cookhouse, wash-house, latrines and a small recreation room equipped with radio and newspapers and writing material. Three 40 lbs. tents were pitched, each capable of holding two stretcher cases. The centre was adjacent to a staging section to which it was originally attached for rations. Eventually the psychiatrist found it possible to look after his own rationing arrangements.

The patient on arrival was given a short preliminary interview at which his condition was broadly assessed. It was important to determine at once whether the case was one in which physical fatigue was the principal factor or whether emotional causes were mainly responsible, because of the great difference in the dose of sedative required in the two groups. The psychiatrist kept well in the battle picture, and he was, therefore, in a position to judge, apart from the patient's own statement, the physical and mental stress to which he had been subjected.

As a routine, patients were next given a substantial meal with as much hot sweet tea as they could be induced to drink. A sedative was then administered, the dose depending on whether the case was considered to be predominantly exhaustive or emotional. The former required only 1 or 2 drachms, of paraldehyde, while with the latter 5 drachms, initially, followed by 2 drachms one hour later was often needed.

Very agitated cases were accommodated, on admission, in the tents where the maximum of quietness was obtainable, and where their disturbed state did not react unfavourably on recovering cases and those about to return to duty.

Sleep for a period of 12 to 24 hours was aimed at, after which the majority showed marked improvement. Next each man was given a bath and a change of clothes. Stocks of clothing and washing materials were held.

On the third day the soldier was given a long interview, and when necessary this was followed by simple psychotherapy. Many improved out of all recognition with nothing more than sleep, food, a wash, and a change of clothing. Abreaction, under pentothal, was not found to be a particularly useful procedure. Better results were obtained by using simple persuasion, explanation, firm encouragement and suggestion. In addition to psycho-therapeutic procedures, the men were supplied with plenty of writing material and books encouraged to use the recreation room, and to listen to the wireless.

The need for greater resources in the way of material for diversional therapy was felt at times. Carpentry tools for example, would have been most useful and would have given an opportunity for manual activity.

The atmosphere of the centre was one of cure. It was not regarded by the men, as the beginning of hospitalisation, but rather as a place to which they had come for a short rest.

A resume of the casualties for the period 24 April 1944 to 31 May 1944 is given in Table I :—

TABLE I

Resume of psychiatric casualties for the period 24 *April* 1944 *to* 31 *May* 1944—*2nd Division* (Total 181 cases).

Disposal		Diagnosis	
Returned to duty	104	Exhaustion ...	62
Hospital	26	Acute anxiety reaction ...	51
Recategorised	23	Anxiety neurosis ...	38
Rear details	10	Hysteria	15
Cases complicated by physical disorders	18	NYD	12
		Reactive depression ...	3

The proportion of psychiatric cases to other battle casualties was approximately 10 per cent. Sixty-five per cent. of patients seen were returned to duty.

It was very difficult to establish a criterion for judging which cases would relapse. So far 12, i.e., approximately 10 per cent. of those returned to duty, relapsed. These relapsed cases were not a dead loss as most of them fought well before breaking down again. Much depended on the morale of the unit to which the men returned. One case, of doubtful prognosis, did extremely well in a battalion, where morale was high, whereas four others, in another battalion, men of apparently good personality, who had been returned fully recovered, relapsed. Those with depression about the loss of comrades, accompanied by marked emotional instability, usually have a good prognosis ; and many such quickly returned to the line. The apathetic individual, with little emotional feeling, did not do well. Those of sound personality, who develop acute anxiety conditions have a good prognosis. The timid, unaggressive individual, of solitary habits, is apt to relapse. He is less tough than the average soldier.

The staff of the centre consisted of three orderlies who had been trained by the psychiatrist. A good cook is most important, as many patients have mild gastric trouble, and some have lost their appetite for days. Palatable and well-cooked food is welcomed.

The low rate of psychiatric casualties in this division is considered to be due to three causes :—

(i) Thorough selection work had been carried out during the training period.

(ii) The high standard of officers and leadership in the division.

(iii) The high morale of the soldiers in the division.

Note : The psychiatrist in this division had been attached to it several months before going into action. This was a great advantage. He was known to all medical officers, and had been accepted as a member of the division headquarters. All forms of transport and equipment were quickly supplied on request. The corps commander, during the fighting, commented on the valuable work which was being done at the psychiatric centre.

(2) *20th Indian Division :* This division was fighting in the Imphal area, at a time when Japanese infiltration was taking place and consequently operations were fluid.

Psychiatric casualties were seen under a variety of circumstances. From 17 March to 1 April 1944, the psychiatrist was attached to an Indian field ambulance. This unit was located in the Moreh defensive position or ' box '. To this ' box ' groups of soldiers who had become casualties, made their way. The psychiatrist had not been long with the division and was, therefore, not well known to medical officers. To avoid missing cases he made a point of seeing all British cases admitted to the field ambulance. Owing to the numbers, it was difficult to see all the IOR cases which may account for the small number of IORs dealt with. In the ' box ' treatment was carried out at the MDS. Cover from shelling was secured by digging in, but there was no head cover. A splinter-proof room would have been a great asset, but it was not possible to make this. Consequently, dealing with psychiatric cases was complex. Nevertheless, more than 50 per cent. of the cases were returned to duty in less than three days.

The first peak of battle casualties was on the 17 and 18 March 1944 for IORs and 18 and 19 March 1944 for BORs. The peak of psychiatric casualties was on 20 and 21 March 1944. A second peak, for BORs was reached on 22 and 23 March 1944. The position was vacated on 31 March 1944 ; and a well-organised withdrawal took place. Treatment under the conditions in the ' Moreh box ', was difficult, but not impossible. When the ' box ' position was first occupied, no one clearly knew the disposition of the troops, or the size of the ' box '. There was a good deal of apprehension about the position of the Japanese, and considerable nervousness was shown once or twice, by a panicky shooting off of ammunition. The troops soon settled down and put up a remarkably good show.

The number of cases seen during the period was 51 (25 returned to duty in category A, 3 in category C, and 23 were evacuated).

Experience showed that the following points were important :—

(i) The divisional psychiatrist should operate not further forward than MDS. The ADS is too mobile to hold cases. Often the ideal place is the forward CCS provided the lines of communication are not too long.

(ii) The holding of cases is most difficult at the MDS.

(iii) Lectures to RMOs and company officers, before active operations, is essential. All units in the division should be informed of the location of the psychiatrist before battle.

(iv) Close co-operation with divisional headquarters and the corps psychiatrist must be maintained.

(v) The admissions should be reclassified into (a) those returnable quickly in the same category, (b) those requiring prolonged treatment who are evacuated with adequate notes, and (c) men unfit for front-line duty who are placed in the lower category and evacuated.

Clinical Notes :

(i) The psychiatrist should see all admissions, otherwise he is liable to miss cases, as medical officers do not always know which cases to send to him.

(ii) Patients should be in a part of the medical unit apart from medical and surgical cases.

(iii) A talk with each patient, if possible for at least an hour to decide whether he should be held, evacuated, or recategorised, is essential.

(iv) In certain instances pentothal was used within the first 24 hours. Those selected for its use were apparently well, but unwilling to return to duty, or to co-operate. Paraldehyde, 4 drachms, morning and night, gradually reducing the dosage as indicated, was most useful. When barbitone soluble was used, at least 22½ grains was given. Morphia and hyoscine were found to be of little value with battle casualties. Morphia grain ½ and hyoscine 1/50 grain often had little or no effect.

It was observed that RMOs seldom gave enough sedation before evacuation. On this matter they required instruction.

On the third day if the patient was doing well, sedation could be reduced to, paraldehyde 1 or 2 drachms, night and morning and whatever occupation was possible such as games (draughts, dominoes, etc.) reading, or digging trenches and constructing dug-in wards, was encouraged.

(v) On the second day psychotherapeutic measures were used, such as superficial analysis, persuasion and suggestion, and reassurance. A thorough physical examination was also made.

(vi) Particular attention was paid to any marked criticism of a unit; and unbiased investigation made, preferably while the unit was in action.

(vii) Heavy sedation was used when evacuating those with a serious breakdown of psychotic or psychoneurotic nature, and full notes accompanied these patients.

(viii) When a man was returned to unit, advice was given through the RMO so that he might be used to the best advantage.

(3) *25th Indian Division:* All patients were seen at the MDS. Despite an atmosphere of tension, and occasionally excessive noise from batteries, the site was considered suitable. A few patients were disturbed, but the remainder did well. An advantage of the situation was that the atmosphere of the front-line was maintained, and hence the contrast, when returning to duty, was not pronounced.

There was little time before going to Burma to do selection and weeding out of unsuitable personnel. The incidence of anxiety conditions was greatest in units not in any definite assault, but holding positions under shell fire. After an assault, the most usual psychiatric malady

was the terror state. Patients were treated chiefly by sedatives, persuasion and suggestion. Most received treatment for less than a week, and were then fit for return to duty. A few were sent to B. Echelon, for a week, as a form of rehabilitation. The toxic factor was very important with Indian troops, many of whom were evacuated to CCS. Subclinical chronic dysentery, malaria or hookworm infections were also common. Insufficient rest, owing to the necessity of having constant patrols and large number of sentries at night, reduced the stability of many who ultimately broke down. Anxiety states occurred commonly amongst British troops, while cases of hysteria, of the conversion type, were confined to Indian troops, and these usually showed paralysis and/or anaesthesia of a limb.

Reinforcements arrived, for the most part, after the severe fighting was over. This was fortunate, because on the whole, they lacked adequate training and were constantly of poor physical make up. They had not been well selected, and many had to be evacuated through medical channels almost at once. Therefore, many of the reinforcements were not seen by the psychiatrist. But their presence was detrimental to morale, and more experienced troops felt that the new arrivals could not be trusted in action.

TABLE II

Summary of psychiatric patients seen between 2 *April* 1944 *and* 25 *April* 1944—25*th Indian Division.*

Psychoneurotic	42
Returned to unit	32 (76 per cent.)
Psychotic	9 All were evacuated to corps level.

(4) 26*th Indian Division:* The division went into action on the Arakan from a rest area, within 48 hours. The initial clash resulted in 12 BOR psychiatric casualties ; 8 were dull and backward, and 4 chronic psychoneurotics. All were evacuated.

When the position stabilised, the fighting consisted of a series of attacks on defended hill features. Exhaustion, with anxiety, was frequent after each action. These patients responded quickly to rest, sedation, good food and simple reassurance. They were seen at the MDS which was close to a gun position. There was also a party of Japanese about 400 yards away. The therapeutic setting, consequently, was not ideal. Therefore, only patients with an obviously good prognosis were kept. They were retained on an average for 5 days and then returned to duty. Gun fire was incessant, and the standard of physical comfort was low. From sunset to dawn there was a constant danger of Japanese patrols. Smoking, talking, or any movement was forbidden during the night. Patients were made as comfortable as possible, and given good food and such other medical comforts as were available. The only sedatives used were medinal and morphia. If a patient did not respond to medinal

grains 15 t.d.s., he was evacuated. There was a shortage of other sedatives as the unit was functioning on a small scale, and on an all pack basis. BORs were encouraged to talk at length about their experiences, most of which were on the border line of consciousness. More elaborate methods were not required. Later, psychiatric work was carried out at a MDS further back but the number seen here were small.

The following points are important :—

(i) During the monsoon, malaria increased, and with it was seen a marked rise in toxic psychosis.

(ii) Medical officers became more psychiatrically minded, as experience of fighting grew, and referred mild as well as severe cases.

(iii) The dilution of British battalions by new drafts altered the standard considerably. The fresh arrivals remained unassimilated, and tended to be a source of lowered morale.

(iv) Physical investigations in BORs often revealed anaemia, splenic enlargement, and infection with worms. When the physical conditions were remedied, psychiatric symptoms often faded.

(v) Morale amongst IORs mainly depended on good leadership and administration. When the men are well fed, given regular leave, and when their religious scruples are respected, they will do anything, and go anywhere. Morale in BORs depended upon their knowing what they were expected to do, unit *esprit de corps*, and sound tactical leadership. These facts also were by no means unimportant in case of IORs. Sorting and selection, unfortunately, was not possible before this division went into action. Had this been carried out, the psychiatric casualties would have been fewer.

Clinical Note : There were several examples of paralysis and analgesia, and many of fits. Fits responded to suggestion under hexobarbitone narcohypnosis. Eighty per cent. in these groups were returned to their units whereas only 50 per cent. of those with paralysis and analgesia responded to treatment at MDS level.

One hundred and six patients were seen between 15 March and 5 May 1944.

TABLE III

Summary of results of psychiatric patients seen between 15 *March* 1944 *and* 5 *May* 1944—26*th Indian Division.*

Disposal	Officers (British)	BORs	IORs
Returned to unit	4	22	34
Evacuated	2	10	24
Referred to corps psychiatrist ...	2	2	6
	8	34	64
Returned to unit	56 per cent.		

(5) 36*th Division:* Period 5 March to 15 April 1944, on the Arakan. This division was not engaged in heavy fighting at this time. A psychiatric centre was set up at the MDS level, to which patients were sent by RMOs. Continuous narcosis was the chief form of treatment used. The patient was kept asleep for two days, encouraged to get up on the third day, and on the fourth day he was up and working all day. Paraldehyde was used, for choice, as the sedative. As a routine, the temperature was taken morning and evening, as a check on attacks of malaria. When men were returned to duty, RMOs were asked to arrange for them to be kept out of actual combat for 7 days, and to give a mild nightly sedative, if necessary. The majority came to the centre without small kit, and it was necessary to maintain a supply of razors, towels, and mess tins. The psychiatrist had been attached to the division some months before it went into action. This proved to be a great advantage. Considerable sorting had taken place and contact had been established with medical and other officers.

TABLE IV

Psychiatric patients seen between 5 *March* 1944 *to* 15 *April* 1944—36*th Division* (*Total*-73 *cases*).

Disposal			Diagnosis	
Returned to unit ...	42	(57 per cent.)	Exhaustion ...	35
			Chronic psychoneurotic	23
Evacuated ...	14		Psychosis	1
Left out of battle ...	17		Other diagnosis ...	5
			Psychiatric ...	9

PSYCHIATRY AT CORPS LEVEL

From the latter part of 1943, till the date of this conference, IV Corps and XV Corps were continuously engaged in active operations. With the opening of the offensive on Kohima, formations of the XXXIII Corps were also in action.

Corps psychiatry in IV Corps, and XV Corps, was reasonably uniform ; and consequently an adequate picture of psychiatry at corps level is given from the report of the psychiatrist XV Corps. Unfortunately equally detailed reports from the other corps psychiatrists could not be included for lack of space.

XV INDIAN CORPS—ARAKAN CAMPAIGN—1943-44

This survey is in four phases. The first was from September to December 1943, when the 5th and 7th Indian Divisions were moving into position and carrying out patrol activity. In the second phase, December 1943 to February 1944, fighting was more active. The third phase, from February to April 1944, was the most intense period. By then the 26th Indian Division and the 36th Division had joined XV Corps. For part of this period the 7th Division was cut off, and subjected

to the most intense shelling, small arm fire, and bombing of the campaign. In the last phase, the latter part of April and May 1944, the fighting died down.

The 81st West African Division was also engaged, but was not served by XV Corps psychiatric organisation, as its casualties were evacuated by air. A few British officers and NCOs of this division were seen. They were of good personality, and their breakdown appeared to be due to the demands called for in leading West African troops.

The corps psychiatric organisation commenced work on 10 October 1943. There was a psychiatrist at CCS level. It was possible, as a rule, for the division psychiatrist to see cases within 6 to 12 hours, or sometimes earlier, after they had developed symptoms.

At corps level, eventually, there was set up a ward in a CCS, for 24 cases. Trained MNOs were available, and four nursing orderlies were attached. A minimum of four orderlies, not necessarily MNOs, is necessary.

Another psychiatrist was at Chittagong where cases, not fit for front-line duties, were sent for downgrading and discharge to a reinforcement camp. Those requiring lengthy treatment, or boarding out, were sent to a base hospital.

The total number of cases seen was 604. Details are set out in Table V. From 10 November 1943, to 1 February 1944, 117 cases were seen, and these included a number of L of C personnel. The remainder were seen from 1 February 1944, to 30 April 1944.

TABLE V

Summary of results—Psychiatry at Corps Level—XV Indian Corps—Arakan Campaign—1943-44.

Diagnosis	British Officers		BORs		IORs	
	Returned to unit	Evacuated	Returned to unit	Evacuated	Returned to unit	Evacuated
Psychosis ...	...	5	...	18	...	66
Exhaustion ...	5	1	85	10	25	1
Psychoneurosis ...	10	1	67	53	48	26
Dull and backward	...	...	1	52	2	5
Disciplinary ...	...	...	3	...	2	...
Psychopathic personality ...	...	...	2	2	...	...
Other	4	...	24	11	33	42
Total	19	7	182	146	110	140

Factors contributing to the increase in numbers were the onset of fatigue in men who had been on the Arakan for several months,

increased intensity of the fighting, the greater number of troops involved, the arrival of troops without jungle training, and later, the setting up of the MFTUs. The opening of MFTUs prevented those with anxiety symptoms, who, in addition, had developed malaria (perhaps deliberately) from being evacuated unnecessarily. It was now possible to treat, and sort, these patients in the corps area.

It is interesting to note that the troops of the 7th Division who were cut off, with no line of evacuation, although subjected to severe shelling, produced few cases. This information was obtained from medical officers as the psychiatrist of this division was killed and was confirmed by the fact that when evacuation from the 7th Division ' box ' became possible, only a small number were sent to the corps psychiatric centre. Those who did break down while in the ' box ', responded well to a few hours sleep with hypnotics.

One type of case did begin to trickle through from the 7th Division ' box ', a week or two weeks, after it had opened, for example, the gunner who had been called upon to do infantry work. He was, usually, a person of good intelligence and good personality, who had done well during active fighting, but developed symptoms a week or so after it was over. The symptoms were mainly of the anxiety type, and some showed hysterical features. They did not respond to treatment.

The causes for these breakdowns appear to be lack of infantry training and the necessity of fighting with strangers from other units. In the ' box ' were some groups not welded as a team.

It was considered that the division psychiatrist could do the best possible work for the corps by : (i) treating the milder examples of exhaustion, (ii) dealing with mild anxiety conditions by reassurance and explanation, and retaining men on duty, (iii) beginning the investigation of psychotic conditions, and starting treatment on those due to malaria, and commencing the treatment of severe anxiety conditions, (iv) advising the officers concerned when morale seemed to be falling, as indicated by an influx of cases. In these instances he should attempt to determine the cause, and propose a remedy. There was one fallacy in assessing unit morale from the number of psychiatric cases : many potential psychoneurotics contracted malaria or dysentery before psychoneurotic symptoms developed. This was noted in a British unit which had few neurotic breakdowns, but an unduly large incidence of malaria, (v) disposing of the dull and backward, and others unsuited for the front line. Ideally this should be done before a unit comes into action : but if this has not been possible, some sorting should be carried out in the front line. The aim was to hold men, and to prevent loss of manpower by evacuation. This was possible with many who were subsequently downgraded, and (vi) carrying out educative work amongst RMOs and combatant officers in the prevention, recognition and handling of early cases.

The corps psychiatrist was able, as a rule, to carry out final sorting of cases in respect of their future military value, because at no time was there a rush of cases, and adequate nursing arrangements, good

accommodation, and facilities for investigation (laboratory, X-ray, etc.) were available at corps level.

Psychoneurotic patients left the corps centres in four groups :—

(i) Fit for front-line duty.
(ii) Fit for base or L of C duties.
(iii) Needing prolonged treatment, i.e., three months or over.
(iv) Those whose army usefulness had ended.

Group (iv) included no British officers or BORs but did include many IORs as it was difficult to transfer them to another job in a lower category. Hence, unless the IOR responded completely to treatment, he was recommended for category E.

Psychotic cases were investigated at the corps centre, and those due to toxic factors were differentiated from those of endogenous aetiology. Ordinarily toxic cases were treated at the centre, and some were returned direct to duty. On the whole this was considered inadvisable, as the majority needed prolonged convalescence.

Early in the campaign an attempt was made to transfer BORs of good intelligence, who had broken down in action, and were unfit for front-line duties, within the corps area, and without downgrading. But there were administrative objections to this and it was given up.

The corps psychiatrist, like the divisional psychiatrist, carried out some selection work, and also gave talks to RMOs and combatant officers on handling the unstable. A difficulty in the latter work is that it takes the psychiatrist from the corps centre which is his primary responsibility.

Except in one British brigade, no selection work had been carried out before the troops arrived in the Arakan. A few reinforcements had been through selection procedures in the United Kingdom.

Clinical Observations on BORs : The clinical types did differ essentially from those reported on in other theatres of war. Psychoneurotics predominated and fell into five groups :—

(i) The term ‘ exhaustion ’ was used for many, of good personality and intelligence, who developed acute symptoms as a result of a severe call upon their physical and emotional stamina. Shelling was an important cause and particularly the unavoidable, and rarely, shelling by our own artillery. Concurrent physical illness was often present in these cases.

(ii) Those with chronic anxiety broke down with less stress than the first group. Their symptoms began when they went into the front line and gradually became worse, until finally they were evacuated by the RMO.

(iii) The dull and backward broke down with the little battle stress. These patients, in Table V, were referred because of psychoneurotic symptoms. They were seldom sent because of the intellectual defect.

(iv) A small group, of good intelligence who, had adjusted fairly well in civil life and in the army, until exposed to battle conditions broke down with little stress and were unfit for further front-line duty. A selection board could have spotted them only with difficulty. A marked personality trait was seclusiveness.

(v) This group included most of those who were psychoneurotics returned to unit. These were, in the main, of good intelligence and background, but very gradually developed mild visceral complaints, thus manifesting their anxiety as somatic symptoms. They responded well to reassurance and explanation, provided conscious battle anxiety was not prominent.

The commonest psychoneurotic symptom was anxiety, with a slow onset. Symptoms were largely subjective but there were usually tremor and a startle reflex. When the onset was acute, patients lay on their stretchers weeping, and jumped at the slightest noise. Unless stimulated they continued as stretcher cases, paying little attention to their fellows or surroundings.

Depression was a familiar symptom, and here the prospect of returning to the front line was poor. Suicidal thoughts, even with retardation or other accompaniments of depression indicated that the patient required downgrading on recovery from the more acute phase.

A reliable prognostic sign, in acute cases, was the amount of sedative needed to induce sleep. If very little, the outlook was excellent. The converse was also true. Some patients, even with large doses of sedatives got little sleep. One was given 15 grains of medinal and 6 drachms of parldehyde with little effect. Eventually he recovered but was fit only for base and L of C duties.

Frank hysterias were rare amongst BORs. Hysterical symptoms occurred in anxiety states, but rarely required special attention. An extremely anxious patient was admitted with aphonia, but as the anxiety settled the aphonia cleared up.

A few with states of stupor were admitted. Objectively they were dramatic, but the prognosis was not necessarily bad. They required longer treatment than the average case of ' exhaustion '.

Examples of anxiety, with confusional features, were also seen. These were caused by severe stress in those of poor personality or poor intelligence. None recovered sufficiently to be sent back to the front line.

A few soldiers ' ran wild ' under stress, and were left with anxiety symptoms. On the whole they did well if intelligence and personality were good, but they needed reassurance as to their sanity.

Treatment : Explanation and reassurance were the main psychotherapeutic procedures used. Abreactive technique with pentothal was occasionally used, but without great benefit. Pentothal was useful in clearing up hysterical symptoms.

In the 'exhaustion' cases, sedation was the keynote in treatment. In some, mild sedation was sufficient, while others had to be kept asleep for one or more days, just being roused for meals. The most useful drugs were parldehyde and medinal. Interviews were given, but on the whole they were not numerous. The interviews began as the patients were recovering as a result of induced sleep. A physical examination was done at the same time. At this stage definite improvement was usual, and the patient became sociable and interested. He asked how

he could re-equip himself, and was obviously keen to return to his unit. He was generally allowed to go back on a date set by himself. An important factor in a man's desire to get back to duty was that he had been an integrated part of his unit. His friends were there and it was his home. So he was anxious to return even if he had to go through the same experience again. Fresh reinforcements, lacking integration in the unit, did not show the same keenness to return to duty.

In Table V headed ' other ' are included those referred for psychiatric examination who had no illness, psychological or otherwise, also those with an organic basis for their symptoms. A number, thought to be psychoneurotic, on examination were found to have amoebiasis. Frequently there was no diarrhoea. In this group, also were included patients who complained of loss of interest, giddiness, headache, backache and sleeplessness. From their symptoms it was difficult to exclude psychoneurosis, particularly if the personality was liable to psychoneurotic breakdown. Generally they had a slight temperature, and it was found wise to examine at least one stool when symptoms suggested abnormal fatigue.

IORs : It was noted how frequently physical factors caused or contributed to their psychological symptoms. It was often difficult to make an exact diagnosis as usually they could not be kept long enough at the corps centre for the physical illness to be treated.

The IOR is subject to hysteria, commonly in the form of ' fits '. Under acute stress, gross hysterical symptoms such as deafness, blindness and tremors were frequent. In most instances these patients responded to simple suggestive measures while conscious or under the influence of pentothal. The IOR was very difficult to deal with if he developed an anaesthesia or paralysis following a slight wound. Patients who complained of weakness, dizziness, vague aches and pains, and even of psychotic symptoms, often had a physical illness, commonly chronic malaria, amoebic dysentery, or hookworm infection. The BSR was done as a routine in all cases of doubtful aetiology.

In spite of the larger number of IORs in the corps they suffered less, proportionately, than the BORs from psychoneurotic illness. Psychosis, on the other hand, was commoner. Table V does not give a full picture in this respect, as psychotics, diagnosed as organic, were included in ' other '. For example, in 7 of the last 11 IORs admitted as psychotic, toxic factors were found.

Delirium, as a symptom of a toxic psychosis, was rare amongst IORs[20]. More often the psychosis was of the stuporous type, and the patient was mute, self-absorbed, inactive, indifferent, neglected food and soiled himself. Sometimes a mood of fearfulness, related to the alleged presence of the hostile force, appeared in a psychotic setting.

The IOR is liable to short psychotic episodes of the maniac depressive and schizophrenic types. If prolonged, the clinical picture

[20] Further observation has shown that delirium as a symptom of toxic psychosis is fairly common in the IORs.

is likely to change rapidly from week to week, e.g., the patient with mild anomalies of behaviour becomes crazy in the lay sense of the term, shortly to revert to his former behaviour.

Indian officers and VCOs developed psychoneurosis of the same type, and for the same causes, as the BORs. Few IORs are included in Table V under the ' dull and backward ' heading. One reason was the difficulty of assessing the level of intelligence except clinically, as tests used on BORs are unreliable for IORs and no others were available.

The Gurkhas, on this front, produced very few cases, whether psychotic or psychoneurotic. The average Gurkha starts with better physical health than the IOR, is perfectly adapted to fighting, and accustomed to the jungle. (The incidence of breakdown amongst Gurkhas, in the IV Corps, was higher).

Prophylaxis : The RMO is the key person. If capable he can prevent men from breaking down, see that mild cases receive early treatment locally, or from the psychiatrist, and supervise the rehabilitation of ' exhaustion ' cases returned to duty. His aid, in this campaign, was enlisted by lectures and informal talks.

Welfare work is most important and was of great help. Often a history of domestic difficulty immediately ante-dated the appearance of symptoms.

The value of previous jungle training was proved in these operations. Jungle trained troops, even those who broke down, never expressed a horror of the jungle. The strain in the jungle is different to that in any other form of warfare, and the hostile force is adept at accentuating it. The greatest difficulty is the night, for the opposing force can appear without being detected. This becomes very wearing, and more so in troops not highly disciplined who are inclined to fire round after round without reason. It is impossible to relax for a single night. The answer to this is short periods of rest, out of the line ; but this is not always possible.

The BOR who fought in Burma and in the Middle East while admitting that his chances of survival in Burma were greater, yet preferred fighting in the open.

Morale amongst the fighting troops was excellent throughout, as can be seen from the small percentage who developed symptoms. It received a ' life ' when it became obvious that the hostile force's favourite tactics of infiltration, and cutting the lines of communication, were doomed to failure.

The morale of the young BOR (aged about 20) should be watched carefully. He had grown up during the war, and does not know, as older men do, of the desperate attempts made to prevent it, and of the alternatives to going to war. Soldiering was the only occupation open to him as he grew up, and he did not particularly like it. It would be unwise to form companies of men entirely in this age-group.

REHABILITATION OF PSYCHIATRIC BATTLE CASUALTIES[21]

The percentage of cases returned to full combatant duty from division and corps centres was in the neighbourhood of 60 per cent. Thus, although forward psychiatry had proved to be a success in saving manpower, and in reducing the number of psychoneurotic cases in hospital, the problem of how to deal with about 40 per cent. of the total cases remained a very real one.

The most striking impression gained of this 40 per cent. was the marked deterioration shown in their conditions as they proceeded along the lines of communication. Their disabilities became rigid and well-defined, and their attitude towards army life deteriorated during the weeks spent in idleness, inactivity, and self-contemplation in hospitals along the route of evacuation to the base hospitals.

If the problems which arose concerning chronic psychoneurotic disabilities after the last war are to be avoided, careful thought must be given to preventive measures likely to reduce the number of these cases.

Practically all men in the army have carried on satisfactorily for a period of from one to two years without showing any gross departure from emotional normality. It is difficult to believe that a single emotional breakdown, under the stress of battle, need necessarily make a previously sound soldier into a chronic invalid. Yet at present this is actually happening.

It is, therefore, suggested that a forward rehabilitation centre, to which men could be sent for intensive remilitarisation, should be established. There, the bonds linking the soldier to the army could be strengthened. The prevailing idea in the centre should be, that the soldier can be made fit for further service in the army, and that there is a job within his capacity.

A small rehabilitation centre was opened in Shillong. The results have been promising.

SEDATIVES AND OTHER MEDICAL SUPPLIES

The Psychiatrist's Pannier : A set of two panniers was issued to divisional psychiatrists. Each contained a supply of drugs and equipment—syringes, bowls, torches, etc. The aim in providing the panniers was to make the divisional psychiatrist independent of supplies from a unit to which he might be attached temporarily. They were of solid construction, and packed carefully, so that they could be carried on mule or jeep. The choice of contents was, to a large extent, limited by what was available when the panniers were issued.

[21] Comments by Adviser in Psychiatry, Eastern Command.

The list of contents is given as an annexure. The contents of the panniers were discussed at the conference, and the following additions were recommended :—

(i) Three stomach tubes size No. 10.
(ii) Ampoules of morphia.
(iii) Ampoules of quinine (grains 5) and tablets.
(iv) One 20 c.c. syringe.
(v) Two BSR tubes, and solution of sodium citrate.
(vi) One lumbar puncture needle.

In the discussion the following observations were made :—

The reliable and quick action of paraldehyde was unanimously praised. Opinion on medinal and phenobarbitone was divided. Some found these drugs disappointing, and avoided them altogether, whilst others used them for mild sedation only, especially with out-patients. Medinal, grains 22½, was considered by many as a minimum initial dose for the sedation of battle casualties.

It was reported that West African troops often required 6 drachms of paraldehyde and even then slept only for an hour or two. Of morphia they needed grain ½ and of hyoscine grain 1/50.

Sodium amytal and evipan were stated to be superior to pentothal, while cyclonal sodium and hexobarbitone were also regarded as satisfactory.

The importance of quinine in controlling psychotic and confusional stages due to malaria (sometimes sub-clinical) was stressed.

RECOMMENDATION FOR WAR ESTABLISHMENT OF CORPS AND DIVISIONAL PSYCHIATRIC CENTRES

The necessary establishment for corps and divisional psychiatric teams was considered. The plan of carrying all psychiatrists in a central pool had worked well, and should be continued. But additional personnel (hitherto supplied under local arrangements) should be on a fixed establishment.

The following proposals were made :—

(i) *At divisional level:*

(a) Personnel attached to divisional psychiatrist:

Driver-batman	1
MNO Class I, rank Corporal	1
MNO Class II or III, rank Private	1
Clerk typist, rank Lance-Corporal	1

(b) Transport : Jeep or 15 cwt. truck 1

(c) Medical equipment—as in psychiatrist's pannier.

(ii) *At corps level:*

(a) Personnel attached to corps psychiatrist:

Graded psychiatrist or trainee (if available)	...	1
Driver-batman	...	1
MNO Class I, rank Sergeant or Corporal	...	1
MNO Class II or III, rank Private ...	...	2
Clerk typist, rank Lance Corporal ...	...	1
General duty or MNO class III, rank Private	...	4

(b) Transport: Jeep or 15 cwt. truck 1

(c) Medical equipment—as in psychiatrist's pannier.

CONCLUSION

The conference was the first of its kind to be held in the India Command. It is noteworthy that about one-third of those present were not army psychiatrists. The presence of officers commanding hospitals and medical specialists meant that the subjects for discussion—and there were many not included in this brief report—were handled in a broad manner and in relationship with military medicine as a whole. And there was a social side to the conference: names previously familiar on reports were identified with human beings, and informal talks supplemented the formal speeches. All this, it is believed, gave an added impetus to psychiatric work in the India Command and in the Fourteenth Army.

ANNEXURE

The Psychiatrist's Pannier

List of contents

Box 'A'

P.V. Nos.	Item	Acct. unit	Quantity
01182	Chlorosol	lb.	1
01292	Glucose	,,	5
01842	Tablets barbitonum soluble grains $7\frac{1}{2}$ ...	Nos.	250
01540	Paraldehyde	lb.	5
01932	Tablets acriflavine grain 0·87	Nos.	400
14036	Bottles hot water	,,	4
14121	Primus stove	,,	2
14178	Measure metal double	,,	2
N.I.V.	Tablets phenobarbitonum grain I ...	,,	500
3001341	Sodii bromide tablets grains 5... ...	,,	2,000

Box 'B'

P.V. Nos.	Item	Acct. unit	Quantity
01302	Hexobarbitonum soluble ampoules of 10 g. with 10 c.c. ampoules sterilised water ...	Ampoules	150
01477	Nikethamide coaamine ampoules of 1·7 c.c. in box of 5 ampoules	Ampoules	50
01789	Hyoscine hydrobromide tubes of 20 tablets	Tube	10
01814	Tablets morphia gr. $\frac{1}{4}$, tube of 20 tablets ...	,,	20
05486	Needles hypodermic	Nos.	18
05642	Scalpel $1\frac{1}{2}$ inches	,,	2
05741	Syringe serum 10 c.c.	,,	3
12141	Wool cotton absorbent	lb.	1
14018	Bowls 10 inches	Nos.	3
14156	Lamp electric hand, no bulb or cell ...	,,	1
14157	Lamp electric hand, bulb for	,,	6
14158	Lamp electric hand, dry cell for ...	,,	12
14248	Thermometer clinical	,,	3
14249	Thermometer clinical, case for ...	,,	3
14257	Trays kidney shaped 10 inches ...	,,	3
3005395	Steriliser miniature Gibb's pattern ...	,,	1
3005422	Syringe all glass 2 c.c. rustless steel needles for	,,	36
3005431	Syringe hypodermic all metal in case without needles	,,	2
N.I.V.	Syringe all glass, 2 c.c.	,,	3
N.I.V.	Forceps dressing 5 inches serrated to point	,,	4
N.I.V.	Syringe exploring all glass P.I. needle for ...	,,	18
05117	Catheter, I.R. size 6	,,	2
05233	Forceps, artery, (Spencer Well's) 5 inches...	,,	2
05792	Tubing, drainage, 5/15 inches ...	,,	1
12101	Lint plain	lb.	1
14066	Brush, nail	Nos.	1
14086	Clip, tubing for	,,	1
14226	Syringe ,enema (Higginson's without nozzle)	,,	1
14227	Syringe, enema (Higginson's) ivory nozzle for	,,	1
15044	Funnel, E. I. 4 oz.	,,	1
14267	Tube, stomach, India rubber, size 19 ...	,,	1
23704	Tin, round 1 lb.	,,	1
23706	Tin, round 8 oz.	,,	2

APPENDIX H

Suggestions for the Formation of a Psychiatric Team Capable of Establishing a Psychiatric Centre During Battle Periods

Suggested 'team'

Medical officer (graded psychiatrist) ...	1
Nursing orderly (MNO)	1
Batman	1

It has been abundantly proved both in the Middle East and in this theatre of war, that the proper treatment of the majority of psychiatric battle casualties is in a centre sufficiently far from the noise and atmosphere of battle to enable the patient to recover his balance but not so far back that a feeling of complete withdrawal from the battle area has been achieved where chronicity and fear of return may in fact be increased.

While it might be desirable to construct a unit which would be specially designed for this function, it is felt that :—

(i) During periods of training and between battles the unit would have little to do.

(ii) There would be a tying up of valuable manpower which might be more effectively used elsewhere when not actually employed as a psychiatric centre.

(iii) The psychiatrist would have to be the commanding officer of the unit and would find his attention constantly diverted by the administrative work of the unit.

(iv) A patient should not be allowed to feel that he has entered a 'special' unit.

It is suggested that the most practical answer to the problem is to be prepared to improvise a small field hospital from one of the following :—

(i) Part of headquarters company of a field ambulance or a complete company.

(ii) Part of CCS.

(iii) An Indian staging section.

To such an improvisation would be attached the psychiatric team. The psychiatrist need have only the broadest control over the administration of the unit. The MNO should be a NCO so that he may have executive control over the nursing orderlies in the unit to which he is attached.

In training periods, the MNO will accompany the psychiatrist in his duties. He will act as his assistant in all his activities, as his clerk when he is preparing reports, and as his clinical assistant. The psychiatrist besides receiving assistance in his basic work will know that when the time of battle comes he has a right hand man versed in his ways, to assist him in the rapid improvisation of a psychiatric centre in association with whatever unit may be made available to him.

APPENDIX I

Memorandum Regarding Discharge from Army of Officers and other Ranks suffering from mental illness[22]

The procedure laid down in paragraph 437 of the *Regulations for the Medical Services of the Army in India*, that officers and other ranks who have suffered from a psychotic breakdown must be discharged from the army, will normally be followed and all such cases will be invalided from military service. This is clearly imperative since these men are not merely of doubtful value to the army but their presence might lead to insecurity in the units.

From time to time medical boards, will however, have before them officers or men whose breakdown, while psychotic in character, has been of short duration, not of a serious type, occurring with severe precipitating cause in an individual with a good personal and family history. Very exceptionally, where legal certification has not been found necessary and an apparently perfect recovery has been made such psychotic patients may be considered for retention in military service provided they have been examined, reported on and certified fit by the consulting psychiatrist to GHQ or by an adviser in psychiatry or, if this is not possible, by a recognised specialist in psychiatry who has not previously examined the patient ; in such cases the officer or soldier will be brought before a medical board and the proceedings sent (with the report and above certificate attached) through the usual channels to the Medical Directorate, GHQ, who will obtain necessary approval for the individual retention.

Para 437 of *Regulations for the Medical Services of the Army in India* is not intended to apply necessarily to cases of mental aberration due to trauma or to intoxications where the cause can be eliminated without leaving permanent serious effect ; nor will it apply to cases which come within the psychoneurosis disease group in the *Nomenclature of Diseases*. An amendment of regulations to this effect is under issue.

This instruction is applicable to Indian and British Services.

[22] Memorandum No. 19899/1/DMS 10(a), dated 14 March 1944.

CHAPTER XXI

Salmonella Enteritidis

Before entering upon a discussion of the incidence of *Salm. enteritidis* as the organism causative of enteric fever, it is necessary clearly to decide not only what is implied by a clinical diagnosis of 'enteric fever' but also what bacteria of the *Salmonella* genus are to be included within the *Enteritidis* species. It may at first sight appear, even to clinicians who have had more than a nodding acquaintance with *Salmonella* infections as well as to experienced clinical pathologists, that a reasonably clear definition of a common clinical syndrome and of not uncommon bacterial species should present little difficulty. It is hoped to show that the problem is much more complex than its title suggests.

CLINICAL ASPECTS OF INVASIVE *SALMONELLA* INFECTION OF MAN

The view is still widely held and taught that *Salmonellae* can be divided into two groups, the organisms of one of which are pathogenic for man in whom they produce a disease differing only in severity from typhoid fever, while those of the other are primarily animal pathogens, incapable of invading the human body and causing no disease other than gastro-enteritis in man. Recent advances in the epidemiology of *Salmonella* infection have rendered this conception no longer tenable. An excellent review of the state of the *Salmonella* problem is that by Bornstein (1943). Almost without exception, those *Salmonella* species formerly regarded as exclusive human pathogens have now also been isolated from animals. Conversely, the great majority of species which were first isolated from an animal source have since been isolated from human infections of one sort or another. Moreover, it is becoming increasingly evident that many of those species formerly thought to be primarily animal pathogens, causing only mild gastro-enteritis in man, are, under certain conditions able to invade the human body and give rise to a generalised infection having a fatality rate comparable with or even greater than that of typhoid fever. Such generalised infections may fall into one of the two clinical categories for which Bornstein (1943) has proposed the names *Salmonella* fever and *Salmonella* septicaemia. The clinical course of *Salmonella* fever is milder and less typical than typhoid fever with the exception of some cases due to *S. paratyphi* A, *S. paratyphi* B, *S. paratyphi* C and *S. sendai*. Fever and malaise are the predominating symptoms and usually last from one to three weeks. Leucopenia is present in some cases and disappearance of eosinophilic leucocytes is common. Slow pulse rate is not a regular sign, neither is enlargement of the spleen. Roseolae were rarely observed. As in typhoid fever there may be bronchitis and bronchopneumonia and *Salmonella* organisms are occasionally found in the sputum. Positive blood cultures are often found early in the disease ; stool cultures may be positive from the beginning, but may remain negative for weeks. Bacteria may be found in the urine. The post-mortem findings may be

entirely non-characteristic, but may occasionally present lesions simulating those of typhoid fever (Bornstein, 1943).

In *Salmonella* septicaemia 'the distribution and pathologic effects of the *Salmonella* are not unlike those of pyogenic *cocci*. In adults, intestinal involvement is usually absent which increases the diagnostic difficulties. Careful study of the history, however, sometimes reveals an attack of diarrhoea preceding the onset by a few weeks. The blood invasion is evident from the high, remittent fever and positive blood cultures, or from the localisation of the infection in various tissues. In infants and young children, where septicaemia tends to complicate the gastro-enteritis cases, meningitis and osteomyelitis develop not infrequently ; there is no place in the human body where a *Salmonella* infection may not become localised' (Bornstein, 1943).

There are thus two main clinical types of invasive *Salmonella* infection which tend to be more or less clearcut, the one conforming, especially in its pyrexial pattern, to a mild variety of the disease usually known as enteric fever, of which the most severe clinical manifestations occur in cases of infection with *Salm. typhi;* the other displays the spiky, remittent fever typical of the coccal septicaemias and is complicated, in the majority of cases, by localisation of the bacteria with pus production in any organ or tissue of the body. Unlike enteric fever due to *Salm. typhi* and *Salm. paratyphi* A and B, cases both of *Salmonella* fever and *Salmonella* septicaemia are usually dispersed and sporadic in occurrence so that detailed information of their natural history is difficult to acquire. Correlation of such information has usually been the work of *Salmonella* reference laboratories, the specialised and extensive nature of whose work often precludes close co-operation with the clinician. Figures relating to human *Salmonella* infection in North America and Cuba for the years 1939 to 1941, and compiled by the New York *Salmonella* Centre (Bornstein, 1942 ; 1943), show that *Salmonella* fever and *Salmonella* septicaemia not only comprise a considerable proportion of all cases of infection due to *Salmonellae* other than *Salm. typhi* and *Salm. paratyphi* A and B, but have a high fatality rate. Table I is a summary of the relevant facts derived from these figures, from which have been excluded all data relating to *Salm. typhi* and *Salm. paratyphi* A and B infections, to carriers and to cases about which no clinical information was available.

TABLE I

Classification of human Salmonella *infections from North America and Cuba* (1939-41).* (*excluding* Salm. typhi *and* Salm. paratyphi *A and B infections, carriers and cases for which no clinical detail was available*).

Type of infection	Number of cases	Percentage of total No.	Fatality rate (per cent.)
Salmonella fever	25	8·4	12
Salmonella septicaemia	48	16·2	37
Gastro-enteritis	223	75·4	1·3†
	296	100·0	...

* Data from Bornstein (1942-43).
† Two out of a total of three deaths occurred in young children or infants.

It is interesting to note that the only case of *Salm. partyphi* C infection recorded in this series was one of gastro-enteritis. The total of 296 cases was made up from infections caused by 29 different *Salmonella* species among which *Salm. typhimurium*, *Salm. cholerae-suis*, *Salm. oranienburg*, *Salm. monteovideo* and *Salm. newport* were most frequently isolated. Although certain species, such as *Salm. typhimurium*, were most frequently derived from gastro-enteritis cases while others, like *Salm. cholerae-suis*, showed a predilection for causing septicaemia, no species of which a significant number of strains was isolated, showed an exclusive association with any one type of infection. For example, of 32 strains of *Salm. oranienburg*, 21 were isolated from gastro-enteritis, 4 from *Salmonella* fever and 7 from septicaemic cases. Figures from the same source show that of 38 strains of *Salm. paratyphi* B from cases of human infection for which data were available, 25 were from cases of *Salmonella fever*, one from a case of septicaemia and no less than 12 from cases of gastro-enteritis (Savage, 1942 ; Feemster and Anderson, 1939).

Table I exemplifies three important points concerning infection with those species formerly regarded as 'animal pathogens'. The first is that in about one quarter of all human infections with such species the organisms invade the body. The second point is that the septicaemic type of infection is about twice as common as *Salmonella* fever. Thirdly, the fatality rate of speticaemia is three times as great as that of *Salmonella* fever. It is clear, therefore, that invasive *Salmonella* disease is an important cause of morbidity and that septicaemia is the more prevalent and serious of its manifestations.

Assuming that these facts should form the background for any discussion of the association between *Salm. enteritidis*, or any other species, and enteric fever, the question arises as to whether the term 'enteric fever' should denote only *Salmonella* fever or should also include *Salmonella* septicaemia within its purview. Although the first alternative is the more logical from the clinical point of view, its adoption in the present instance would result in an artificial division of what is essentially one problem, that is the acquisition of invasiveness by a *Salmonella* species formerly regarded as non-invasive and the symptomatology which may follow invasion. It is proposed, therefore, to consider the bacteriological and clinical aspects of generalised *Salm. enteritidis* disease rather than to limit discussion to any particular clinical syndrome.

THE BACTERIOLOGY OF *SALM. ENTERITIDIS.*

Before considering the relationship of *Salm. enteritidis* to human disease it is essential to understand something of the methods whereby the identity of *Salmonella* species can be determined, and of the history of the development of these methods. Without this knowledge there are neither the means of defining the species *Salm. enteritidis* with accuracy nor any criteria by which to judge the value of the recorded isolations of this species during the years which have intervened since it was first described by Gaertner in 1888.

The species of *Salmonella* is determined by analysis of the antigens of which it is composed. *Salmonellae* typically possess two principal

kinds of antigen, one of which characterises the flagella (H) and the other the body (O) of the organism. The body usually consists of a complex of O antigens, some or all of which may be shared by other related species which are, therefore, said to belong to the same O-group. The flagella may possess one or more H antigens. Apart from this, the flagella of the majority of species undergo an alternation between one and the other of two distinct antigenic structures. This is known as diphasic variation. The antigens of the flagella in one of these phases are more or less species-specific (phase 1 or specific phase), while the antigens of the alternate phase are shared by the flagella of a considerable number of diphasic species in the same phase (phase 2 or group phase). A relatively small number of species are not diphasic; their flagella remain stable and contain phase 1 antigens only. Such species are called monophasic. All *Salmonella* strains which are identical in both somatic and flagellar antigenic structure belong to the same species.

Although the presence in a *Salmonella* species of distinct flagellar and somatic antigens had been demonstrated as early as 1903, it was not until 1917, when Weil and Felix reported a similar complexity in *Proteus* X strains, that the possibilities of qualitative antigenic analysis were fully realised. Diphasic variation was discovered in 1922 (Andrewes, 1922). It was not until 1926, that the first semblance of a reliable system for the classification of *Salmonella* species, in accordance with their antigenic structure, was initiated by White (1926, 1929) and later extended by Kauffmann. The Kauffmann-White Scheme, under which each species is distinguished by an antigenic formula, has now received universal recognition. In this system the antigens of the bacterial body are designated by Roman numerals, those of one flagellar phase (specific) by small letters and those of the second (group) phase of diphasic species by Arabic numerals.

It is seen, therefore, that a period of about forty years elapsed between the first isolation and description of *Salm. enteritidis* and the evolution of a proper system whereby one *Salmonella* species could clearly be distinguished from another. During this period serological identification was based mainly on the presence of major flagellar antigens in the strain, because antisera produced by immunisation with motile organisms usually possess a very much higher titre against the flagellae than against the bacterial bodies. Since many *Salmonellae* species differ from one another only in one or more of several flagellar antigens and cannot be distinguished except by the use of absorbed, monospecific antisera, any association of certain species with specific infective processes, reported prior to the publication of White's initial work on classification, must be open to doubt.

Salm. enteritidis was first isolated by Gaertner in 1888, from the meat of an emergency-slaughtered cow which had caused an outbreak of food-poisoning in all the fifty-eight persons who had consumed it. One of these persons, who had eaten an inordinate amount of the meat, died and the same organism was isolated from his spleen at post-mortem. The species is monophasic and belongs to the O-group D. Within this group are twenty-two other species, including *Salm. typhi*, all of which possess the same major O antigens, IX and XII. Of these

species seven, including *Salm. enteritidis*, are monophasic and are characterised by the flagellar antigen 'g'. (Topley and Wilson, 1946). They are[1] :—

Salm. enteritidis —	I,	IX,XII;	g,	m.........
Salm. dublin —	I,	IX,XII;	g,	p.........
Salm. rostock —	I,	IX,XII;	g,	p, u.....
Salm. moscow —		IX,XII;	g,	q.........
Salm. blegdam —		IX,XII;	g,	m, q.....
Salm. pensacola —		IX,XII;	g,	m, t.....
Salm. berta —		IX,XII;	f,	g, t.....

An antiserum prepared against any one of these species will agglutinate suspensions of both motile and non-motile strains of any of the others to approximately the homologous titre. These species, therefore, can only be differentiated by means of antisera which have been rendered specific for the flagellar components' 'f', 'm', 'p', 'q', 't' and 'u' by absorption of heterologous agglutinins. The first species to be distinguished from *Salm. enteritidis* in this way were *Salm. dublin* (White, 1929-30), *Salm. moscow* (Hicks, 1929-30) and *Salm. rostock* (Kauffmann, 1930). The remaining species were not recognised until considerably later—*Salm. blegdam* in 1935, *Salm. berta* in 1937 and *Salm. pensacola* in 1945 (Topley and Wilson, 1946).

In addition to subdivision of the *Salmonella* genus into species on antigenic grounds, some workers have attempted further to subdivide some species into types or varieties by means of fermentative and other biochemical tests. Such elaboration of an already complex system of classification is, in general, to be deprecated in the absence of evidence either of the stability of the biochemical mechanisms involved or of any constant association of the types with definite patterns of biological behaviour. Four main varieties of *Salm. enteritidis*, all possessing identical flagellar and somatic antigenic structures, have been differentiated by means of biochemical tests. Since there is evidence of a correlation between one of these varieties and invasive human infection, the subdivisions of this species warrant further discussion. The four varieties are :—

(*i*) *Salm. enteritidis* var. *jena* (or *gaertner*)—This is the original variety isolated by Gaertner, and subsequently from numerous epidemic and sporadic cases of food-poisoning in man. It appears to be the principal variety causing gastro-enteritis following ingestion of infected meat (Topley and Wilson, 1946,).

(*ii*) *Salm. var. danysz* was originally isolated from field-mice by Danysz in 1900. Another strain was isolated from the urine of a sick child in 1902. This second strain, under the name of "Ratin bacillus" and 'Liverpool Virus', has been widely used for the extermination of rats (Leslie, 1942).

(*iii*) *Salm.* var. *essen*, first isolated in 1935, is primarily a pathogen of ducks in Germany and Holland but can produce gastro-enteritis in man, the organism apparently being capable of transmission by duck eggs.

[1] Minor antigenic components are omitted.

(*iv*) *Salm.* var. *chaco* was first isolated from the blood of each of ten cases of continued fever during the Paraguayan – Bolivian (Chaco) War (Savino and Menendez, 1934, 1935). The variety has since been isolated from many cases of invasive human infection in India (Hayes and Freeman, 1945). No record exists of its isolation from any source other than man.

The fermentation reactions whereby these varieties can be distinguished are given in Table II (Kauffmann, 1935, Leslie, 1942).

TABLE II

Fermentative reactions of varieties of Salm. enteritidis.

Variety	Peptone water	Bitter's medium			Stern's glycerol medium
	Dulcitol	Glucose	Dulcitol	Arabinose	
Jena	+ 24 hours	+	+	+	+
Danysz ...	+ 24 hours	—	+	—	—
Essen	— 24 hours	+	—	—	+
Chaco	— 24 hours	+	∓	+	—

In deciding upon those species or varieties hereafter to be denoted by the name *Salm enteritidis* the restraints of dogmatic taxonomy should clearly not be allowed to detract from the subsequent discussion. It is now generally accepted that the pathogenicity (if not the invasiveness) of *Salmonella* species is to a considerable extent a function of the O antigens, while the flagella exercise little or no influence on the host-parasite relationship (Schutze, 1930). With the exception of *Salm. typhi* which possesses an additional surface antigen (Vi), all the species within O-group D share the same somatic antigens and might, therefore, be expected to show the same potential pathogenicity. This is not the case. Some species, such as *Salm. gallinarum,* are very seldom the cause of human disease, and then only of gastro-enteritis, while others, as *Salm. sendai,* appear to be primarily associated with enteric fever. If only those species are considered which are closely related to *Salm. enteritidis,* sharing with it the flagellar component 'g', equally marked differences in invasive capacity are found. *Salm. rostock* (I, IX, XII ; g, p, u.........), isolated from cattle has not yet been isolated from man (Topley and Wilson, 1946). On the other hand, *Salm. dublin* (I, IX, XII, g, p.........), also indigenous in cattle, shows a marked tendency to cause human invasive disease. (White, 1929-30, Smith and Scott, 1930; Guthrie and Montgomery, 1939; Hayes and Freeman, 1945). *Salm. blegdam* (IX, XII ; g, m, q.........) originally isolated in Denmark

from the blood of a patient suffering from pneumonia, has been reported as the cause of fifty cases of *Salmonella* fever and septicaemia among Australian soldiers in New Guinea and of two cases of invasive infection in North America (Fenner and Jackson, 1946 ; Atkinson, 1946, Hayes and Freeman, 1945 ; Holt and Newton, 1948). These facts strongly suggest that a most useful line of enquiry and research would be to determine why *Salmonellae* having apparently identical somatic antigens should differ so markedly in their invasiveness for the human body. It is evident that if two varieties of one species, having the same somatic and flagellar antigens but with clearly defined pathogenic roles, could be found, they would present an ideal starting point for such an investigation. Considerable evidence exists that such varieties are found within the species *Salm. enteritidis* and, since sufficient data are available for consideration, it is proposed to obey the taxonomic rules and restrict discussion to this species alone.

SALM. ENTERITIDIS AS THE CAUSE OF INVASIVE INFECTION OF MAN

The association of *Salm. enteritidis* with explosive epidemics and sporadic cases of gastro-enteritis is too well recognised to require further discussion, though it may be mentioned that this species is much less frequently the cause of food-poisoning than *Salm. typhimurium* (Topley and Wilson, 1946). Systemic infection due to *Salm. enteritidis* is usually regarded as a rarity and most of the published reports of its occurrence begin with a statement to this effect. Up to 1939, about one hundred cases had been reported (Savino and Menendez, 1934 ; Huang, Chang and Lieu, 1937 ; Guthrie and Montgomery, 1939). In so far as is possible cases from which strains originally described as *gaertner* were isolated but subsequently shown to belong to another closely related species such as *dublin* (White, 1929-30 ; Smith and Scott, 1930), are not considered in the following summary. It is important to remember, however, that the identity of strains isolated from the majority of these cases, of which the original reports have been available, were not confirmed by serological cross-absorption tests with known *Salm. enteritidis* strains. It is possible, therefore, that some of them may in fact have been species such as *Salm. dublin* or *Salm. blegdam* with which this discussion is not primarily concerned.

Analysis of ninety-four cases shows that they fall into two clinical categories viz., infantile and adult cases.

Infantile Cases : Forty-one cases fall into this category, the largest series, being that of Guthrie and Montgomery (1939) who reported twenty-seven cases occurring within a few weeks, of one another; all children under two years of age and the majority in the first year of life. The initial symptoms of these cases were vomiting and diarrhoea. Ten of the fifteen cases who died showed a purulent meningitis, while *Salm. enteritidis* was isolated from the meninges of two others. In four cases, purulent cholecystitis was present while the causative organism was isolated from the bile of eleven at post-mortem. In all the infants who died there was strong presumptive evidence of spread of infection by the

blood stream. Most of the other reports relating to this category are of isolated cases, some of them primary, others following an initial gastro-enteritis, the majority of whom succumbed to meningeal infection. Bacteriological diagnosis was confirmed by cross-absorption tests in twenty-nine of the forty-one cases. The only strains subjected to biochemical investigations sufficient for type determination were those isolated from Guthrie's and Montgomery's cases and these appeared to belong to the *jena* variety, though atypical in their reaction in Stern's glycerol medium. All those other strains isolated from infantile infections, of which it has been possible to acquire evidence of fermentative reactions, have produced acid rapidly from dulcitol and therefore, probably belong to either the *jena* or *danysz* varieties.

Bornstein (1943), reviewing the manifestations of *Salmonella septicaemia*, ranks *Salm. enteritidis* as the predominant species in the causation of meningitis and confirms that this type of infection is found mainly during the first year of life.

Adult Cases: Fifty-three cases belong to this category and of these forty-six occurred either in debilitated persons or in association with other diseases. Ten cases, showing symptoms of typhoid or paratyphoid fever, from which *Salm. enteritidis* var. *chaco* was isolated by blood culture, were reported from the Gran Chaco in South America as occurring among wounded or sick soldiers at a time when typhoid fever, dysentery, malaria and pulmonary infections were prevalent. When these epidemics died out, cases of invasive *Salm. enteritidis* infection were no longer found (Savino and Menendez, 1935). Nine of a series of eighteen cases reported from Peiping (China) by Huang, Chang and Lieu (1937) were suffering from concomitant relapsing fever while all, with one exception, were undernourished persons in poor health. The predominant symptoms and signs in these cases were continued high fever for a few days followed by a low fever for weeks or months, bradycardia, enlarged spleen and a rash consisting of profuse, haemorrhagic spots. The fatality rate in this series was 53 per cent., including three cases complicated by meningitis. Six of the fatal cases developed a terminal bronocho-pneumonia. One case was complicated by subcutaneous abscess formation. Another series of seventeen cases reported from Japan (Chochiro Hayasaka, 1933; quoted by Huang *et al.* 1937) occurred during the malarial treatment of neurosyphilis. One case was of a man suffering from a gunshot wound of the chest (Gregg and Hayes, 1921).

Only seven adult cases which were definitely primary in origin had been reported up to 1939. These include three cases reported from China (Li and Ni, 1928; Tang, 1933—quoted by Haung *et al.*, 1937) and three from Britain (Rosher and Wilson, 1921; McNee, 1921; O'Callaghan, 1945). The causative organism was not isolated from Rosher and Wilson's case, diagnosis being based, with considerable justification, on the serological reactions of the patient's serum. A case of meningitis in a boy of eleven years, reported from Jerusalem by Stuart and Krikorian (1926) has been included here since it cannot be classed as infantile. With this single exception, all the

primary cases appear to have suffered from continuous fever with little or no evidence of preceding intestinal involvement and to have conformed, more or less, to the clinical picture of *Salmonella* fever.

Of thirty-one strains of which details of biochemical and serological characteristics are available, ten were of *chaco* type. All the eighteen strains isolated from the cases reported by Huang *et al.* (1937) failed to ferment dulcitol after 24 hours incubation, but the identity of none of these strains was confirmed by cross-absorption tests. The strain isolated by Li and Ni, also a late-dulcitol-fermenter, was, however, serologically confirmed as *Salm. enteritidis*. All these nineteen strains may, therefore, have been either of *chaco* or *essen* variety. On the other hand, the strain from Stuart and Krikorian's case was a rapid fermenter of dulcitol, was identified serologically by Felix and later checked by White (1929-30). The strain from McNee's case was also a rapid-dulcitol-fermenter but its identity was not serologically confirmed, nor, apparently, was that reported by O'Callaghan, although 'serologically it showed greater affinity to the *Gaertner* than to the *Dublin* variety of *B. enteritidis*'. Fermentative reactions of this latter strain are not on record.

If all the cases of adult infection are grouped together and compared with the infantile cases, the outlines of a rough but suggestive epidemiological picture can be perceived. The infantile cases were most frequently heralded by acute gastro-enteritis which was followed by systemic spread, with elective localisation in the meninges. The geographical distribution of cases appears to have been almost exclusively European, while those infecting strains of which adequate bacteriological information is available, were rapid fermenters of dulcitol and, therefore, of the *jena* (Guthrie's and Montgomery's strains), or possibly *danysz* variety.

The adult cases differed from the infantile in almost every respect. They were mainly uncomplicated cases either of *Salmonella* fever or of septicaemia with little evidence of preceding or even concomitant enteritis. The majority of cases have been reported from South America and the Far East. From the fifty-three recorded cases, the behaviour towards dulcitol of thirty-one strains, which were certainly or probably *Salm. enteritidis*, is known. Of these, ten were *chaco* variety and nineteen slow dulcitol fermenters and, therefore, probably either *chaco* or *essen* varieties. Only two strains were isolated which fermented dulcitol after overnight incubation, one from a British soldier in France (McNee), the other from Stuart's and Krikorian's case of juvenile meningitis.

It should be pointed out that generalisations based on so little precise information are apt to prove misleading. For example, emphasis should not be laid on slow fermentation of dulcitol as indicating *chaco* or *essen* varieties in the absence of proof that the strains concerned were indeed *Salm. enteritidis*, for this is also a fermentative peculiarity of the distinct but related species, *Salm. blegdam* and *Salm. moscow*. Both of these species and the former in particular are known to cause invasive human disease (Fenner and Jackson, 1946; Hicks, 1929-30). Again, sporadic infection affecting isolated individuals is a less dramatic event than is an epidemic affecting the well-being of a community and

so attracts less attention and is less fully investigated, although the epidemic may actually involve a smaller total number of persons. Whereas it is often justifiable to assume the diagnosis of cases occurring during an epidemic period, every sporadic case must be diagnosed independently and on its own merits, especially when a particular bacterial species is to be incriminated as the unusual cause of a common clinical syndrome. It thus follows that those sporadic cases which are hospitalised, which undergo a full and competent bacteriological investigation and which are eventually recorded in the literature, must comprise a very small and unrepresentative sample of all cases which occur. This will especially be so in those countries where medical facilities are themselves sporadically distributed. It is evident from the short review given above that the most thorough bacteriological investigations were, as a rule, carried out on a series of cases, observed in one locality over a limited period of time, so that at least a proportion of the cases may have had a common origin even though the origin was not revealed by epidemiological investigation. This may lead to undue bias in favour of the causative role of a particular variety of organism isolated from the cases of one or two large series and underestimation of the importance of other varieties reported as having infected isolated cases.

In the light of these fallacies, the most that can be said for the classification given above is that it represents an arbitrary attempt to correlate such scanty information as was available up till 1939. It does, however, form a useful suppositional background against which more recent knowledge of *Salm. enteritidis* infection, gained in India from 1943 to 1945, can be studied.

INVASIVE *SALM. ENTERITIDIS* INFECTION IN THE ARMY IN INDIA

Prior to 1945, only four isolations of *Salm. enteritidis* from cases of systemic infection were reported from India, one by Goyle and Shaikh (1943) and three by McDonald (1944). All were cases of continued fever, the organism being isolated by blood culture. The three strains from McDonald's cases were identified by serological cross-absorption tests and failed to ferment dulcitol after overnight incubation.

Details of the incidence of *Salmonella* infection in the Army in India were published in 1945, from the Bacteriology Department of the Central Military Pathological Laboratory, India (Hayes and Freeman, 1945). One of the duties of this laboratory (formerly the Enteric Laboratory, Kasauli) was the verification of bacteriological diagnosis of all *Salmonella* species isolated by military laboratories in India and, for a time, in the SEAC. The data on which the relative incidence of infection by various species was assessed was the number of strains of each species received by the laboratory for identification. Criticism of the statistical validity of figures obtained in this way is applicable to all extensive surveys of the kind which usually preclude close co-operation with clinicians. The principal sources of error which should be taken into account are :—

(i) Some laboratories did not submit the *Salmonellae* isolated by them for verification. It is also probable that those laboratories which did utilise the services of the Central Laboratory, nevertheless, failed to send all their primary isolations.

(ii) The species received for verification were not necessarily a fair sample of those isolated, since there is a tendency to forward only those species most difficult to identify. This would give bias to the rarer species and diminish the apparent incidence of commoner species.

(iii) The number of cases from which the causative organism is isolated do not necessarily form an accurate index of the true number of infections. They do, however, coincide with the number of bacteriologically proven cases which alone are relevant to the present discussion.

The figures have the merit of dealing only with primary isolations and are not, therefore, confused by the error of duplication. During the years 1941 to 1944 (both inclusive) the number of isolations of both *Salm. enteritidis* and *Salm. paratyphi* C rose markedly and progressively. The annual number of strains of these species submitted for identification over the four year period is compared with the equivalent number of strains of some other *Salmonella* species in Table III.

TABLE III

Number of strains of various Salmonella *species received for identification,* 1941-44 *at the Central Military Pathological Laboratory, India* (Hayes and Freeman, 1945).

Species	Number of strains				
	1941	1942	1943	1944 plus 6 weeks 1945	Total
Salm. typhi ...	166	318	394	421	1299
Salm. paratyphi A ...	60	52	93	76	281
Salm. paratyphi B ...	5	0	2	0	7
Salm. paratyphi C ...	4	4	20	82	110
Salm. enteritidis ...	0	7	48	56	111
Salm. dublin ...	0	0	2	12	14
Salm. typhimurium ...	3	3	2	10	18

That the increase in the number of isolations of *Salm. enteritidis* was not due simply to the rapid, expansion of the Army in India during the war years, is shown by comparison with the figures for *Salm. typhi* and *Salm. paratyphi* A, infection, both of which are endemic in India. In addition to the isolations recorded in Table III, thirty-nine further strains of *Salm. enteritidis* were received up to October 1945, bringing the total number of strains to 150. It is known that a further considerable number of strains were isolated after that date. It is reasonably

certain that the figures began progressively to decline after the end of 1944.

Two unusual features were noted about this relatively large outcrop of *Salm. enteritidis* infections. In the first place they were sporadic, one or two strains only being sent at a time from widely separated laboratories. Secondly, almost all the strains were isolated from the blood or from other sources indicating invasion of the body. The distribution of the various sources from which 136 strains were isolated are as follows :

Source	Number of strains
Blood	124
Pus	3
Spleen (Post-mortem)	1
Bile (Post-mortem)	2
Urine	3
Faeces	3

Thus 91 per cent. of strains were isolated from the blood and 98 per cent. from a source indicating invasion of the body.

BACTERIOLOGY OF INDIAN STRAINS OF *SALM. ENTERITIDIS*

All the strains were initially identified by simple agglutination tests using unabsorbed O-antiserum, and component-specific H-antisera in order to exclude those species having flagellar antigenic structures closely related to that of *Salm. enteritidis*. The somatic antigenic structure of a considerable number of strains was investigated in detail by the cross-absorption technique and the antigens IX and XII only were found to be present (Hayes and Freeman, 1945 ; Hayes, 1947). Cross-absorption tests have similarly been used to confirm the identity of the flagellar structure of a few strains with that of two strains of typical *jena* variety.

All the strains (with the exception of one anaerogenic variant) produced acid and gas from glucose, maltose, mannitol, arabinose and rhamnose after 24 hours incubation but did not produce indole. The great majority, however, failed to ferment dulcitol in peptone-water until the fifth day of incubation and frequently much later. In the case of one strain, acid was not produced until the seventeenth day. It was further observed that while the late-dulcitol-fermenting strains were always derived from the blood or from some other source indicating invasion of the body, two serologically typical strains, one of which was isolated from a guinea-pig and the other from the faeces of an infant suffering from acute, uncomplicated gastro-enteritis, fermented dulcitol rapidly.

Three late-dulcitol-fermenting strains isolated from blood were sent for confirmation of identity to Dr. Joan Taylor of the *Salmonella* Reference Laboratory for Great Britain, who reported them as *Salm. enteritidis* var. *chaco*.

The biochemical characteristics of thirty-six of the Indian strains of *Salm. enteritidis* were investigated in detail in comparison with

known strains of *jena*, *danysz*, *essen* and *chaco* varieties and also with the original *chaco* strains isolated by Savino and Menendez. Of the thirty-six strains, thirty-one which were originally late-dulcitol-fermenters, were found to be *chaco* type while five, which originally fermented dulcitol overnight, were typical *jena* strains. Three of the *chaco* strains had been isolated from empyema pus, from urine and from the spleen respectively of cases of continuous fever. The remaining twenty-eight strains were from the blood. Of the five *jena* strains, two had been isolated from the faeces of cases of uncomoplicated gastro-enteritis, one from an abscess in an Indian soldier, and one from a guinea-pig. The source of the remaining strain is not known. So far as can be ascertained, these five *jena* strains represent the total of this variety identified as *Salm. enteritidis* since the end of 1942 by the Central Military Pathological Laboratory, India.

EPIDEMIOLOGY

The facts stated above suggest :—

(i) That the *jena* variety of *Salm. enteritidis* has in the past been an uncommon cause of disease in military establishments in India and that, although it may occasionally invade the body, its principal role is to cause gastro-enteritis.

(ii) That the cases of invasive *Salm. enteritidis* infection recently found in India were caused almost exclusively by the *chaco* variety. This variety has not yet been shown to have been responsible for simple gastro-enteritis in man, nor has it yet been isolated from an animal source.

(iii) That the *chaco* variety was not indigenous in India but exotic, since there is no evidence that it existed either in India or in Burma until 1942, while, thereafter, the incidence of infection by it rose out of all proportion to the expansion of the army.

There is considerable circumstantial evidence that *Salm. enteritidis* var. *chaco* was introduced into Burma and India by the Japanese Army. The incidence of isolation of the species did not begin to rise until the end of 1942, after the Japanese invasion of Burma and India, but then increased progressively to a peak towards the end of 1944. Of the seven strains identified by the Central Laboratory during 1942, four were received in December of that year. Moreover, a considerable proportion of the strains received during 1945, were isolated from the blood of the Japanese prisoners of war.

It has already been mentioned that cases appeared to have occurred sporadically. Their geographical distribution, judged by the locality of the laboratories where the strains were isolated, was concentrated mainly in the north-east of India. Thus during 1943, 1944 and the first six weeks of 1945, 42 per cent. of the strains were isolated in Calcutta, the principal base of operations against the Japanese, and 28 per cent. in forward operational areas of the Burma Campaign. The

remaining 30 per cent. of strains were from areas having no obvious connection with Burma. It should be remarked that these strains were received mainly during 1943. The concomitant rise and fall of *Salm. enteritidis* and *Salm. paratyphi* C infection (Table III) suggest that both species may have had the same epidemiological source. Nearly 80 per cent. of *Salm. paratyphi* C isolations were associated with the operations in Burma. A pathologist in charge of a field laboratory on the Burma front, stated in his epidemiological observations concerning the association of this latter species with the Japanese that on several occasions he had noted that when the Indian Army reoccupied a village, which had originally been free from *Salm. paratyphi* C and then held for some time by the Japanese, cases of *Salm. paratyphi* C infection occurred.

CLINICAL ASPECTS OF *SALM. ENTERITIDIS* VAR. *CHACO* INFECTION

It is unfortunate that few clinical particulars of any value are known about the bulk of cases from which the Indian strains of *Salm. enteritidis* were isolated, apart from what can be inferred from the source of isolation. It is probable that the majority of cases belonged to the category of primary infection in adults since all were of adult males employed in military service. The possibility of a preceding attack of malaria is, of course, difficult to rule out but, since examination of the blood for malaria parasites was a routine procedure with all cases of pyrexia of unknown origin, it is likely that the presence of malarial infection would have been mentioned on the form accompanying at least some of the cultures received for identification. This was not the case.

The racial distribution of infection, although predominantly among Indians, as might be expected, was by no means restricted to them. Of 122 strains, 95 were isolated from Indians, twenty from Europeans and seven from Japanese. Hayes and Freeman (1945) remark that the type of infection was a septicaemia with little or no evidence of preceding intestinal involvement, their statement being based on the very high percentage of strains isolated by blood culture, the extremely small number of faecal isolations, and on the fact that no reference to intestinal symptoms was made in the brief clinical notes which accompanied a proportion of the strains. They also state that there appeared to be a tendency towards localisation of infection with pus production, though this was less marked than with *Salm. paratyphi* C, and tentatively assess the fatality rate at between five and ten per cent.

There is thus no indication as to whether the predominant clinical syndrome was that of *Salmonella* fever or septicaemia. Reference has already been made to three cases occurring in Indian soldiers, one of which was fatal, reported by McDonald (1944). The strains isolated from these cases were serologically *Salm. enteritidis* and did not ferment dulcitol. It is possible that these strains were included in Hayes and Freeman's series, and probably, in the light of subsequent findings, that they were of *chaco* variety. In each case the disease was characterised by prolonged fever and abdominal discomfort, though no gastro-enteritis

was present. *Salm. enteritidis* was isolated from the blood of each, but not from the faeces or urine of one of the cases whose excreta was examined. Two of the cases showed chest symptoms. The fatal case showed no marked features at post-mortem examination and no obvious intestinal involvement was apparent apart from prominence of the lymph follicles.

One case of infection of an Indian soldier by a late dulcitol-fermenting strain of *Salm. enteritidis* was reported as displaying all the signs and symptoms of typhoid fever, including a typical rash.

It has already been mentioned that the symptomatology of the ten South American cases from whom the original strains of the *chaco* variety were isolated was that of typhoid or paratyphoid fever. Further clinical particulars of these cases are not available. It is possible, however, that some of the adult cases of invasive *Salm. enteritidis* infection reported from China were due to the *chaco* variety since the strains isolated from these cases appear to have been late fermenters of dulcitol (Li and Ni, 1928 ; Huang *et al.*, 1937). This is especially so in Li and Ni's case, the strain being a proven *Salm. enteritidis.* The common outstanding features of these cases were :—

(i) Sustained high fever for four or more days in the second week of the disease, followed by low fever for from about ten days to as long as three months.

(ii) Absence of diarrhoea at the onset of the disease, although diarrhoea sometimes occurred at the end of the first week or later. Many cases were constipated.

(iii) A profuse rash covering the whole of the body and consisting of bright red, round haemorrhagic spots, about 1 to 3 mm. in diameter, which were not elevated and which did not fade on pressure.

(iv) Broncho-pneumonia and intestinal haemorrhage were the most frequent complications, meningitis and subcutaneous abscesses occurring in a few cases.

Apart from the South American and Indian strains, three strains of *Salm. enteritidis* var. *chaco* have been identified in England by Dr. Joan Taylor who very kindly furnished such brief clinical notes as were available of the cases from whom they were isolated. One, isolated in 1944, was from a liver abscess in a British naval officer recently returned to England from Chittagong (Bengal), who was a long standing case of amoebic dysentery. Another, also isolated in England, was from an army private, but no information is available as to whether or not he had been in India. The third was obtained in 1947, from the pus of a lung abscess in a Jamaican, who was taken ill on a voyage from India to England and who subsequently died from his infection.

One further case of infection with the *chaco* variety of *Salm. enteritidis* has been reported from Batavia (Gispen and Stibbe, 1947). This case was one of septicaemia with localisation in the testis and occurred secondarily to other infections. The organism was isolated both from the blood and from the testicular abscess.

THEORIES OF BACTERIAL INVASIVENESS

General Considerations : Invasive infection in infants has not been considered here for it is well established '(1) that a high morbidity and mortality from *Salmonella* infections in animals is found essentially in the young ; (2) that human infants and young children are very susceptible to *Salmonella* infections, and (3) that the well-known clinical differences between human infections with *Salm. paratyphi* B and *Salm. typhimurium* are not very marked in young children' (Bornstein, 1943). It is possible that particular susceptibility of young animals to invasive disease may be due to poor development of natural antibodies, the presence of which in the serum of adults effectively suppresses the establishment within the body of small numbers of invading bacteria. It is evident that any normal system of defence may be overwhelmed if the number of invading organisms is great, so that we may provisionally accept the proposition that invasive infection of adults by *Salmonella* species which normally cause only gastro-enteritis is due either to the invasion of unusually large numbers or to some defect in the external defence system of the body such as absence of hydrochloric acid from the stomach.

The intrinsic differences between the ability of *jena and chaco* varieties of *Salm. enteritidis* to establish themselves within the adult human body is a problem of different nature. These two varieties appear to have the same somatic and flagellar antigens so that natural or immune antibodies capable of acting on the one might be expected to act equally well upon the other. There can be little doubt that the majority, at least of the Indian cases of *chaco* infection among army personnel, had been actively immunised, prior to the infection, with TAB vaccine so that the invasive capacity of the strains isolated from them is all the more striking.

In order that bacteria may invade the body, they must first make effective contact with the skin or mucous membrane which forms the body wall. In the case of the intestinal pathogens this usually implies penetration of the mucus which covers the intestinal mucosa. A breach must then be made in the wall itself either by mechanical injury or toxic destruction of the cells forming it, or by penetration between the cells. Once a bridge-head has been established inside the body the bacteria must be able firstly to survive the defence mechanisms of the host, and then to multiply. The principal weapons with which the body attacks invading bacteria are the phagocytic activities of leucocytes in the presence of plasma and the bactericidal action of the natural (or immune) antibody and complement of the plasma itself. In addition to resisting the activities of leucocytes, antibodies and complement, bacteria must find, in the body fluids, a medium suitable for supporting their growth and in the cells, chemical substrates susceptible to attack by their soluble products if invasion is to progress to established infection.

It is now generally supposed that pathogenic bacteria evolved accidentally by a process of mutation from a merely saprophytic ancestral form, the mutant organism happening to have acquired some mechanism

which enabled it to resist the defences of the host's body. The operation of a number of these mechanisms is now understood. For example, some invasive bacterial species produce enzymes such as hyaluronidase, mucinase and fibrinolysin which facilitate the spread of the organisms and their toxic products into and through the tissues of the body. Production by bacteria of an enzyme, leucocidin, which destroys leucocytes clearly favours the establishment of infection. A more passive type of bacterial defence is the production of a capsule which ensheathes the body of the organism and, by mechanically preventing its union with antibody, inhibits both phagocytosis by leucocytes and killing by complement. Among *Salmonella* species, the Vi (virulence) antigen of *Salm. typhi*, although not morphologically demonstrable as a capsule, appears to belong to this category. This antigen, discovered by Felix and Pitt (1934, a, b) is heat-labile and, in the majority of freshly isolated strains, completely covers the bodies of the organisms so that they are inagglutinable by O antiserum. It enhances the invasiveness of *Salm. typhi*, probably by protecting the organism against opsonisation by natural or immune O anti-bodies and subsequent phagocytosis during the early stages of infection. (Bhatnagar, 1935 ; Felix and Bhatnagar, 1935). Felix and Pitt (1936) have also described the presence of heat-labile surface antigens in *Salm. paratyphi* A and B and *Salm. typhimurium*. They believe these to be 'virulence antigens' similar in function to that of *Salm. typhi*, although they are serologically distinct from *Salm. typhi* Vi, fail to mask the somatic antigens and, therefore, do not protect the bodies of the species possessing them from phagocytosis in the presence of O antiserum. The heat-labile antigens of *Salm. paratyphi* B. and *Salm. typhimurium* are serologically identical with one another and with the somatic antigen V which had for a long time been regarded as a normal O antigen in spite of its relative lack of resistance to heat (Kauffmann, 1936). For these reasons the contention of Felix that the invasive tendencies of *Salm. paratyphi* A and B in man is ascribable to these antigens is not generally accepted. If Felix is indeed correct in his opinion, any explanation of how these 'Vi' antigens facilitate invasion or of why *Salm. typhimurium*, which is similarly endowed, is classically the cause of gastro-enteritis and not of *Salmonella* fever or septicaemia, is still lacking.

The pathogenicity of *Salmonella* species is dependent on the presence of O antigen, rough strains which have lost this antigen being avirulent. Although the polysaccharide-lipoid complex of which the O antigens are composed is, therefore, necessary for virulence and is probably responsible for the toxic manifestations of *Salmonella* infections, it does not appear to play any part in determining either invasiveness or the ability of *Salmonellae* to multiply in the body. Bovin (1939) was unable to demonstrate any quantitative or qualitative difference between the O antigen complex of two smooth strains of *Salm. typhimurium* which showed an enormous disparity in mouse virulence. More recently, Maale (1948), comparing the properties of a non-invasive but otherwise virulent variant strain of *Salm. typhimurium* with those of the invasive parent strain, could detect no difference between the two strains in respect of morphology, colonial smoothness, antigenic

structure or susceptibility to phagocytosis. The invasive strain, however, showed a much higher resistance to the killing action of complement *in vitro*.

The role of insect vectors in promoting the establishment of invasive infection should not be forgotten. Micro-organisms such as the malaria parasite and the pathogenic rickettsiae, and *Pasteurella pestis* in lesser degree, owe their invasiveness to their adaptation to blood-sucking insects in the bodies of which they can survive and multiply.

APPLICATION OF THESE THEORIES TO THE INVASIVENESS OF *SALM. ENTERITIDIS* VAR. *CHACO*

Hayes and Freeman (1945) investigated the possibility that invasive Indian strains of *Salm. enteritidis* might possess a heat-labile somatic antigen analogous to those of *Salm. paratyphi* A and B and *Salm. typhimurium*. Rabbits were inoculated with suspensions of strains freshly isolated by blood culture, and the resulting antisera were absorbed with immunising suspension which had been treated with hydrochloric acid, as advocated by Felix and Pitt (1936), or boiled to destroy 'Vi' antigen. After absorption, a residual agglutinin remained which agglutinated the immunising suspension, treated with alcohol to destroy flagellar agglutinability, in dilutions of up to 1 : 160 to 1 : 320 absorbed sera prepared in this way were tested, using slide agglutination, against fourteen strains of *Salm. enteritidis*. Thirteen of these strains, isolated by blood culture and now known to have been *chaco* variety, reacted strongly while the remaining strain, isolated from the stool of a case of gastro-enteritis, did not react at all. Five strains of *Salm. dublin* also failed to be agglutinated as did *Salm. moscow*, *Salm. rostock*, three strains of *Salm. typhi* and several strains each of *Salm. paratyphi* A, B and C. This work has since been repeated and confirmed by Hayes using, for absorption, both heated suspensions and suspensions treated with alkali against which the usual O antigens are resistant. The use of *Salm. enteritidis* var *jena* suspensions for absorbing var. *chaco* antisera has yielded equivalent results. Two major difficulties have been noted in the demonstration of this heat and alkali-labile antigen. Firstly, it is of very low antigenicity so that only a proportion of rabbits inoculated produce a demonstrable antibody against it. The second difficulty is more complex in nature. Like other species belonging to O-group *D*, the majority of strains of *Salm. enteritidis* var. *chaco* examined possess the antigen XII_2. Kauffmann (1941) showed that this antigen is subject to a type of variation comparable to that of the flagella in diphasic variation. If a colony of a species containing antigen XII_2 is plated and daughter colonies tested for agglutinability by a XII_2 antiserum, it is frequently found that while some are agglutinable, others are not. If an agglutinable colony is then plated, a minority of its daughter colonies are inagglutinable. If one of these inagglutinable colonies is plated in turn, the contrary state of affairs is observed. There is evidence that the heat-labile antigen of var. *chaco*, although distinct from antigen XII_2, undergoes variation in

association with it. Thus, the antigen has only been identified in colonies having a demonstrable XII_2 antigen. On the other hand, it has been shown to be present in every strain of var. *chaco* tested from which it has proved possible to obtain colonies showing XII_2 agglutinability. Among these are a number of the original South American strains supplied by Dr. Kauffmann. The antigen has never been demonstrated in XII_2 agglutinable colonies of *Salm. enteritidis* var. *jena* nor of any other *Salmonella* species. Attempts to demonstrate an antigen of similar type in var. *jena* have been consistently unsuccessful.

The conclusion seems warranted that there exists an antigen which is specific for strains of *Salm. enteritidis* var. *chaco* which also possess the antigen XII_2 and that this specific antigen conforms in its susceptibility to heat and alkali to the so-called ' virulence antigens ' observed by Felix and Pitt in certain other species. *Salm. enteritidis* does not possess the relatively heat-labile somatic antigen, V, referred to above. Whether or not the antigen is connected in any way with the invasiveness of var. *chaco* strains has not been demonstrated.

A number of var. *chaco* and var. *jena* strains of *Salm. enteritidis* have been examined in parallel for the production of such invasion-promoting enzymes as hyaluronidase, coagulase, fibrinolysin and leucocidin with negative results. Moreover, strains of each variety, with and without XII_2 antigen, showed equal susceptibility to phagocytosis in the presence of human plasma and leucocytes.

Apart from methods of invasion which depend solely on the physiological functions of the bacterial cells themselves, there is the possibility that certain epidemiological factors may be the ultimate determinants of the difference in pathogenicity between the *jena* and *chaco* varieties of *Salm. enteritidis*. One of these factors is that of host adaptation. Those *Salmonella* species which are host adapted to man, and the reservoir of which is the human carrier, appear more prone to cause *Salmonella* fever than do the species which are naturally pathogenic for animals and birds. For example, *Salm. paratyphi* B and *Salm. typhimurium* possess identical O and ' Vi ' antigens. The former species most frequently causes *Salmonella* fever, the source of the infecting strain being a temporary or permanent human carrier or a case. Human infection from an animal source has rarely, if ever, been described (Savage, 1942). *Salm. typhimurium*, on the other hand, is the pre-eminent cause of infective gastro-enteritis and only rarely invades the body. The usual reservoir for human infection by this species is the rodent, although human carriers may have been responsible for a small number of outbreaks. There can be little doubt that host adaptation plays an important role in determining the character of bacterial infection though the reasons for the resulting alteration in the host-parasite relationship are quite unknown.

Salm. enteritidis var. *chaco* differs from the *jena* variety in never having been isolated from any natural source other than man, or from the human body in any condition other than invasive infection. Both varieties can produce septicaemia in white mice when administered

orally (Savino and Menendez, 1935). It is, therefore, not unreasonable to assume that the *chaco* variety, unlike the *jena*, is host-adapted to man and that its invasiveness is the outcome of such adaptation.

A second epidemiological factor which should be borne in mind is transmission by an insect vector. It has been pointed out that adult systemic infection with *Salm. enteritidis*, and especially with the *chaco* variety, appears to be almost exclusively a disease of hot climates and that an overwhelming majority of cases have occurred in debilitated persons living under poor sanitary conditions or in soldiers engaged in active service. Such an environment has long been recognised as especially favourable to the spread of insect-borne diseases. It is clear that adaptation of a variant of *Salm. enteritidis* to survival in the body of blood-sucking insect would confer upon it great advantage, in the causation of invasive infection, over other varieties not so adapted, for it would have found a ready means of direct entry into the body. While there is no real evidence that human infection with *Salm. enteritidis* has been spread by insect vectors, half of the series of cases reported by Huang *et al.* (1937) were suffering from concomitant relapsing fever and *Salm. enteritidis* was isolated from the bodies of lice derived from these patients. Reitler and Menzel (1946) showed the presence of *Salm. enteritidis* in a tick from a bitch which was recovering from an illness and had agglutinins against the same organism in her blood. Experiments carried out by Varela and Olarte (1946) to demonstrate the possibility of transmitting *Salm. enteritidis* by *Pulex irritans* and *Ctenocephalus canis* were, however, unsuccessful. *Salm. moscow* was first isolated from many cases of relapsing fever during an epidemic in Russia in 1922 (Hicks, 1929-30) and it is worth noting that both the somatic antigens and the biochemical characteristics (including late fermentation of dulcitol) of this species are almost identical with those of *Salm. enteritidis* var. *chaco*.

LABORATORY DIAGNOSIS

The methods and technique used in the laboratory diagnosis of *Salmonella* fever and septicaemia in general are equally applicable to similar types of infection with *Salm. enteritidis*. Blood culture offers the greatest promise of isolating the organism and should be continued at intervals throughout the disease until a positive result is obtained. McDonald (1944) has pointed out that isolations may be made from the blood late in the disease. Culture of both faeces and urine should also be carried out at intervals from the onset of infection since the chances of isolation will thereby be increased. At least two good selective media, such as desoxycholate-citrate agar and the medium of Wilson and Blair, should be used in parallel for faecal culture.

When a presumptive strain of *Salm. enteritidis* has been isolated, it is essential that its identity should be confirmed by serological cross-absorption tests with an established strain. It is also very desirable that the biochemical variety to which it belongs should be ascertained. Attention should be paid to the rapidity of fermentation of dulcitol and to the reactions of the strain in Bitter's sugar media and in Stern's glycerol medium (Table II).

The Widal test is of only minor importance in diagnosis. It should be remembered that *Salm. enteritidis* shares somatic antigens with *Salm. typhi* and with twenty-one other species of Group D, so that O-type agglutination is unlikely to be of any value in distinguishing between them. The observed titre of O agglutinins varies widely, depending on the conditions of the test and the method of reading employed and, since these are rarely defined, it is almost impossible to obtain any precise information of value from the literature. Huang *et al.* (1937) state that of their fourteen cases from whom samples of sera were tested one or more times against either the patient's own organism or a stock culture of *Salm. enteritidis*, eight showed agglutination with a titre at or above 1 : 160. The negative results may have been due to the fact that the tests were carried out too early in the disease. 'Agglutinins were first observed on the eighteenth day of disease. All the patients tested after the fourth week showed a positive reaction......... of the six sera containing agglutinins for *S. enteritidis*, which were tested at the same time for O agglutinins against *B. typhosus*, the latter were present in significant titre in three instances. On the other hand, (in one case) there were no typhoid O agglutinins, although the titre of agglutinins for *S. enteritidis* was 1 : 280. In two instances typhoid O agglutinins were present in a titre of 1 : 160, when there were no agglutinins for *S. enteritidis*. In these cases cross-agglutination of *B. typhosus* H and other members of the *Salmonella* group was also seen, though almost invariably to a lower titre than the somatic agglutinins. Some pertinent observations in typhoid fever have been made and cross-agglutination of *S. enteritidis* in fourteen of the seventeen cases was studied. The titres of these group reactions, however, were low in every instance but one, lower than that of the typhoid somatic agglutinins'.

The two cases in McDonald's series on whom successive Widal tests were performed showed a rising O titre against *Salm. typhi*, but only in one did the titre rise above 1 : 320 (Felix's technique). In neither of these cases was a significant *Salm. enteritidis* H titre present. This is an important observation since it shows that, as in typhoid fever, the absence of a significant H or O titre or both, never excludes the possibility of infection. The presence of a *Salm. enteritidis* H titre of 1 : 50 or over, however, probably offers strong presumptive evidence of infection in an area where gastro-enteritis due to this species is not endemic, since an anamnestic rise in titre should not be conditioned by TAB prophylaxis.

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CHAPTER XXII

Schistosomiasis

Andreasen and Suri (1945) drew attention to the case of Lahira Singh, of Talapur village, District Ambala, who had never left India, suffering from *S. haematobium* in IMH Rawalpindi. The disease, however, had already received serious attention when the 82nd West African Division was sent to India. These troops were from Gold Coast and Nigeria where *S. haematobium* and *S. mansoni* are endemic. The 1st West African Brigade early in 1944, had a course of water training at Epe in Southern Nigeria and was very heavily infected with both *S. haematobium* and *S. mansoni*. It was known that there were no suitable intermediate hosts in India but a review of literature did not give any definite evidence that such hosts were non-existent. The civil authorities were also very much concerned as the introduction of another blood destroying disease might further add to the misery of the Indian population. The GHQ, India decided that all personnel of the African division would be investigated. Immediately the DDMS, Eastern Command, got the intimation that African troops were being posted in Ranchi area the ADP (Lieut.-Colonel S. Narain) was detailed to investigate the problem and render an immediate report.

After preliminary investigations instructions were issued to prevent contamination of local water supplies. Bathing in ponds was prohibited and proper disposal of urine and faeces was enforced. By 29 July 1944, a team consisting of medical officers, jemadar laboratory technicians and staff arrived in Chas, where the division was located, to carry out the investigation. Four teams were organised and each was equipped with a centrifuge, two microscopes, test tubes, slides, etc. The work was so organised as to carry out 1,200 to 1,500 stools and urine examinations daily and in all 22,317 African troops were examined. Urine and faeces of 2,061 showed ova of *S. haematobium* and of 38 ova of *S. mansoni*. During the treatment it was observed that in individuals with very scanty ova in the urine, injection of antimony preparation often led to the demonstration of ova in the urine or an increase in the number of ova in those cases where they had previously been scanty.

TRANSMISSION EXPERIMENTS

In June and July 1944, Mukerjee, Bhaduri and Narain (1946) started a survey of gastropod molluscs in Ranchi area. This area was pre-eminently suitable for a high snail population. Snails were collected from all over the area as well as from other parts of Bengal and Assam. They were identified and immediate transmission work was started at the School of Tropical Medicine, Calcutta. Two experiments were carried out with snails of Ranchi area. In the first, ova of *S. haematobium*, concentrated by sedimentation of urine, were added to water containing snails. In the other about 700 freshly hatched

miracidia were added to water with snails. Twenty-nine *Indoplanorbis exustus*, seven *Acrostoma variabile*, twenty-one *Limnoea luteola*, two *Melanoides tuberculatus* and forty *Vivipara bengalensis* were used in these experiments. All except five *Acrostoma* died within four weeks. The dissection of these five snails gave negative results. Similarly transmission experiments with 1,127 snails collected from the Calcutta area showed no parthenitae. The number of snails exposed and their mortality is shown in Table I.

TABLE I

Number of snails exposed to S. haematobium and S. mansoni and their mortality.

Snails	Total number exposed		Total number died		Died 4–28 days		Died over 28 days		Sacrificed	
	S. haematobium	*S. mansoni*	*S. haematobium*	*S. mansoni*	*S. haematobium*	*S. mansoni*	*S. haematobium*	*S. mansoni*	*S. haematobium*	*S. mansoni*
Acrostoma variabile ...	1	2	...	1	0	1	0	0	1	1
Bithynia pulchella	200	50	69	6	5	5	64	1	131	44
Gyraulus convexiusculus ...	159	36	125	20	19	5	106	15	34	16
Indoplanorbis exustus ...	59	59	51	43	10	32	41	11	8	16
Limnoea luteola	169	12	164	12	94	10	70	2	5	0
Melanoides lineatus	101	26	64	13	9	2	55	11	37	13
Melanoides tuberculatus ...	57	21	29	3	3	1	26	2	28	18
Vivipara bengalensis ...	142	33	67	8	12	4	55	4	75	25
Total	888	239	569	106	152	60	417	46	319	133

Later investigations on an extensive scale were carried out by GHQ Parasitology Research Team under Major J. Hsu. Hsu (1945) examined 130,000 snails comprising 16 different species. No normal host (*Bulinus*, *Physa* or *Planorbis*) of schistosoma infective to human being was found. Ten per cent. of snails contained cercariae and 0·43 per cent. contained schistosoma cercariae. None of them, however, were human type. Nine thousand snails were used for transmission experiments and 4,000 of these on dissection after six weeks gave negative results. During this investigation the original discovery of the life cycle of *Schistosoma indicum* was made.

The above investigations showed that there was no likelihood of schistosomiasis becoming established in India.

The disease was common also in East African troops. No 150 East African Hospital reported, eighty-eight cases including fifty-five vesical, thirty-one rectal and two rectal and vesical during July-September 1945. Two cases were of interest as they passed *S. haematobium* in urine and *S. mansoni* in stools. Total figures of schistosomiasis cases in

Indian troops during World War II are not available. An outbreak of the disease occurred in the 7th Gurkhas in Persia during 1941. Two cases amongst VCOs and IORs were reported in SEAC during 1945.

PATHOLOGY

Pruritis of varying intensity depending on the length of exposure and sensitivity of the individual is noticed at the place of entry of the *Schistosoma* cercariae. Brackett (1941) experimentally exposed the skin of the inner aspect of the forearm to *Cercaria elvae* and *C. stagncolae.* Sections of the skin were examined at intervals. Sections of the affected areas showed no cercariae after 29 and 60 hours. Acute inflammation and burrows were, however, seen. The burrows of the 29 hour old lesion were traced from section to section from the point of entry to the blind end within the malpighian layer. 'For the most part the lesions were almost completely filled with neutrophils which in places formed intraepithelial abscesses. Generalised oedema in the vicinity of the burrows and in the cutis and the subcutaneous tissue below them was pronounced. Lymph vessels were dilated and easily seen'. In 56 hour old lesion some burrows were filled with 'loosely arranged debris in some places'. 'Above some of the burrows were oedematous infiltrations between the malpighian layer and cornified tissue. The acute inflammatory reaction seemed to have subsided considerably but in contrast to the picture in the earlier section a striking invasion of eosinophils had occurred'. It will be seen that the cercariae do not penetrate the malpighian layer.

S. haematobium : The blood vessels may show petechiae at the point of entry of cercariae. Urticarial rash may be seen after some days. Toxic febrile reaction may be noticed after an interval. Leucocytosis and eosinophilia are then often found on blood examination. Ova may be deposited in tissues. Urinary bladder shows proliferation of epithelial cells giving rise to hyperplasia and round cell infiltration. There may be papillomatous growth and inflammation of lower segment of bladder mucous membrane. Inflammation may extend to urethra, ureters and kidneys. Ovaries, cervix and vagina in the females and testis and prepuce in the males may be involved. Ova may in some cases infiltrate liver, spleen, appendix, heart, lungs, cords or even brain.

S. Mansoni and S. Japonica : In case of *S. mansoni* lesion is chiefly in the intestines. Koppisch (1942) after examination of 246 specimens with eggs of *S. mansoni* concludes that 'the fundamental histopathological unit of the disease is the pseudo-tubercle developing about ova. The development of the pseudo-tubercles is traced from the early stage of eosinophilic and polymorphonuclear response through that of an epithelioid cell nodule to the final healed fibrous body. There are in addition, chronic inflammatory changes leading ultimately to fibrosis, especially in liver and colon. From the beginning the disease is primarily hepatic and colonic. Pathological changes are instigated mainly by deposition of ova in the tissues; in the colon, this leads to colitis and in the liver to cirrhosis which is periportal in distribution. Splenomegaly

develops in part at least, secondary to portal obstruction. The involvement of the liver and colon and other viscera increases rapidly with severity and duration of the infection. The main anatomico-pathological alterations are divided for purposes of description into cirrhosis, splenomegaly, colitis, pulmonary alterations, ascites, oesophageal varices, retroperitoneal fibrosis, sclerosis and thrombosis of the portal veins and tributaries, bilharzial pigmentation, subserous nodules of intestines, pseudo-tubercles and inflammatory changes. *S. japonicum* is also characterised by invasion of intestines by ova, tissue destruction and proliferation of tissue and cirrhosis of the liver. Johnson and Berry (1946) found in their cases characteristic pathological lesion on sigmoidoscopy in 67 per cent. of cases. The biopsy also showed distinctive small yellow nodular lesions, especially at rectosigmoid junction.

Silveira (1945) suggests that *S. haematobium* has easier access to the lung by way of vesical plexus and iliac vein while *S. mansoni* can reach lung only by way of porto-caval anastomosis.

Espin (1942) reported pseudo Negri bodies in the motor neurones of the affected medullary zone.

SYMPTOMS

The details of the symptoms observed in the African cases during their stay in India are not available. Consultant physician in tropical medicine to GHQ West African Headquarters in his note of 21 June 1944, has, however, made the following interesting observations regarding these cases.

A number of them noted itching and prickly sensation lasting for an hour or two (few had disturbed sleep for the whole night) after they had been in the water lagoon. (As no steps were taken to investigate the cause of skin irritation, it appears that the complaint was of minor nature). Earliest symptoms like fever, headache, vague abdominal pain, diarrhoea and urticaria were noted in February. The incubation period was of about 35 days. As there were repeated opportunities for infection, the incubation period might have been shorter. Some Europeans, however, did not develop any symptom even for eight weeks. There were also many cases who had no symptoms and during the investigation were found to be excreting ova. This is not surprising as symptoms in cases reported elsewhere have been found even after more than two years. Urticaria on the face, lips, proximal portions of upper limbs and occasionally trunk was noticed in early stages. Some degree of eosinophilia, especially in the first or second day of illness was usually found. Temperature in most cases ranged from 100° F. to 101° F. but in one case reached 105° F. The headache was post orbital. Suffused conjunctivae and pain at the back of the neck were sometime noticed. Vague abdominal pain and discomfort were frequent. Blood and mucus were found in stool. Stools with a small trace of russet coloured mucus on the surface was often noticed. Pain in the region

of the bladder was very infrequent. Spasmodic unproductive expectoration was common. A few had definite bronchitic symptoms.

DIAGNOSIS

The diagnosis depends on finding ova in urine and stools. It was not always easy to find this especially in the acute phase of the disease. Sedimentation method was helpful. Very good results were obtained from the examination of scrapings taken through the proctoscope from the small yellow nodules (Faust, Wright, McMullen and Hunter, 1946). Cystoscopy and sigmoidoscopy, especially the former in case of *S. haematobium* are of great help in diagnosing the disease. The importance of cystoscopy as a test of cure in relapsing cases requires special emphasis. Complement fixation tests using an alcoholic extract of livers of *Planorbis* snails infected with *S. spindale* were found useful. Cutaneous test and X-ray of the chest in case of pulmonary schistosomiasis, are useful adjuncts.

TREATMENT

The epidemic amongst West African troops provided a good opportunity to study the effect of various drugs in the treatment of schistosomiasis.

The following observations on stibophen, anthiomaline and tartar emetic are mainly based on the note of the consultant physician, tropical medicine, GHQ, West African Forces, and the *Report on the outbreak of schistosomiasis* by the ADMS, 82nd West African Division.

Stibophen : All Europeans who were exposed to infection were given the following course of stibophen injections in Nigeria :—

1st day	... ...	1·5 cc.
3rd day	... ...	3·5 cc.
5th-17th day	... ...	5·0 cc. (on alternate days) = (Total 40 cc.)

One hundred and fifty-nine Europeans who had schistosomiasis received eleven injections (total 50 cc. stibophen). Seventy-one out of eighty-seven so treated relapsed on arrival in India. All Europeans found positive were admitted to No. 37 IGH(C) for a further course of 60 cc. to 70 cc. of stibophen. Six hundred and twenty Africans were also treated in Nigeria with a course of 40 cc. stibophen each. No figures of relapse rate amongst them are available. Many of them, however, were found positive and had to be treated again. Toxic effects of stibophen reported included lassitude, anorexia and joint pains. Fever, loss of weight and liver enlargement were reported in a few cases. Coughing at night was common. Only two cases out of 466 (0·4 per cent.) treated in India developed abscesses.

Anthiomaline (*Antimony Thiomalate of Lithium*) *:* The 2nd and 4th Brigades were treated in India with anthiomaline. This was also given intramuscularly, the length of treatment being 24 days. By 24 August

1944, 2,278 cases were under treatment. In a series of 1,800 patients, 120 cases (6·7 per cent.) developed intramuscular abscesses. One of these cases died from the effects of a large abscess in the buttock.

Tartar Emetic (*Sodium or Potassium Antimony Tartrate*) : Approximately 4,000 Africans were treated in Nigeria with tartar emetic. The usual course of injections was as follows :—

1st day	...	1/2	grain dissolved in 10 cc. of distilled water.
2nd day	...	1	grain ,, ,, ,, ,, ,, ,,
3rd day	...	1½	grains ,, ,, ,, ,, ,, ,,
5th day	...	2	grains ,, ,, ,, ,, ,, ,,
7th to 21st day daily		2½	grains ,, ,, ,, ,, ,, ,,

The relapse rate amongst these cases was remarkably low.

A number of toxic reactions were reported. Carefully recorded reactions in 1,680 patients receiving intravenous injections of tartar emetic are given below.

Toxic reactions and intercurrent diseases	Frequency of symptoms	Percentage frequency of symptoms
Toxic reactions		
Cough	170	10·12
Retching and vomiting	125	7·44
Abdominal pain and colic	25	1·49
Aching and stiffness in joints	20	1·19
Temperature above 100° F.	12	0·71
Headache	11	0·65
Haematoma at site of injection	10	0·60
Abscess at site of injection	9	0·53
Pain in chest	7	0·41
Pain in neck	6	0·35
Rash at elbows	5	0·30
Urticaria	4	0·24
Bronchitis	4	0·24
Pneumonia	4	0·24
Phlebitis	3	0·18
Diffuse papular rash	2	0·12
Bradycardia	2	0·12
Icterus	2	0·12
Syncope	2	0·12
Sudden haematuria	2	0·12
Acute diarrhoea	1	0·06
Sacral pain	1	0·06
Intercurrent diseases		
Malaria (MT infection)	10	0·60
Pyomyositis	2	0·12
Infective hepatitis	1	0·06
Herpes zoster	3	0·18

The cause of death in six cases was attributed to treatment. The post-mortem findings in five of these cases were as follows :—

(i) Pulmonary embolism.
(ii) Portal pyaemia with multiple abscesses in the liver.
(iii) Softening of the brain with no obvious infarct.
(iv) Massive haemorrhages into the left frontal lobe with old standing cirrhosis and recent acute necrosis of the liver.
(v) Sudden death while apparently in good health, 48 hours after the last injection, heart muscle and liver fatty.

It will be obvious that a course of 50 cc. stibophen was not sufficient to cure schistosomiasis and anthiomaline intramuscular injections gave rise to abscess formation in a large number of cases. Tartar emetic although giving toxic reactions appeared to be the drug of choice.

Work of Alves, Alves and Blair and Girgis and Aziz is of great interest in this connection. Alves (1945) and Alves and Blair (1946) reported a course of treatment lasting only two days consisting of 1 grain to 2 grain injection of sodium antimony tartrate. None of the 100 cases so treated were passing eggs after two months. Alves (1946) has still further reduced the course to one day. A group of 131 Africans in the following three dosage scheme was treated by the slow injection method :—

Group A —6 grains sodium antimonyl tartrate in 3 doses of 2 grains at 4 hours' interval.

Group B —7½ grains sodium antimonyl tartrate in 3 doses of 2½ grains at 4 hours' interval.

Group C—8 grains sodium antimonyl tartrate in 4 doses of 2 grains at 3 hours' interval.

No marked toxic reactions occurred and the results were the same in the three groups. Only seven cases were passing a few dead eggs after two weeks and only one after four weeks but no living eggs were passed. Girgis and Aziz (1948) treated sixteen cases with sodium antimony tartrate and nine cases on a six day course. Their results were as follows. The relapse rates on two day and six day courses were 31 per cent. and 33 per cent. respectively. 'All patients who were cured ceased to pass ova and had no microscopical haematuria by the end of the third week after treatment. In eight cases ova were still passed and there was microscopic haematuria. Of the relapsed cases two received a second course of treatment and ceased to pass ova or blood in urine. Severe immediate reactions and electrocardiographic changes were encountered after the two-day treatment but these were milder and less common after the six-day treatment.'

Kikuth and Gonnert (1948) and Vogel and Minning (1948) tested Miracil D (1–diethylamin–oethylamino–4–methyl thioxanthane) on animals infected with *S. haematobium*. This drug is still in experimental stage.

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CHAPTER XXIII

Sprue

INTRODUCTION

Throughout the campaign in Assam and Burma sprue ranked as a major medical problem. The influx of cases first rose during the fighting around Imphal and Kohima in the winter of 1943-44. The number of cases remained high (especially early in 1945 around Meiktila) until Rangoon was reoccupied in May 1945. The importance of sprue as an invaliding disease is well illustrated by the large number of cases evacuated to the United Kingdom from February 1943 to February 1946, through the Medical Review Board of India. During this period 18,808 cases were reviewed by the board; of these 8,846 were medical, 5,110 surgical and 4,852 psychiatric. More than one-fourth of the medical cases were due to amoebic or bacillary dysentery (1,254 cases) and sprue (1,073 cases). The average period a sprue case spent in hospital before evacuation to England was about one year. It will be obvious, therefore, that sprue was responsible for a good deal of wastage of manpower. Treatment with high protein diet and liver produced good immediate results, but it was not found possible to retain patients for sufficient time to effect full remission or cure, with the result that many men leaving India still had symptoms, and a variable period of further hospital treatment awaited them before their final disposal could be decided. This large number of cases presented many problems of diagnosis and treatment. The different opinions regarding aetiology, diagnostic criteria, the methods of dietetic therapy, and the value of liver, all betoken the extent of present medical ignorance on the subject. Lack of sufficient cases and laboratory facilities for adequately controlled investigations have always been two of the stumbling blocks to a further understanding of the aetiology of sprue. In order to make use of the unique opportunity afforded by this large number of patients, an investigation unit was set up in the summer of 1945 by the Medical Directorate GHQ, India. This Sprue Research Team was attached to No. 3 IBGH, Poona. Since all the cases for evacuation ex-India passed through that hospital, maximal opportunity for collection of cases was available there; the laboratory work was done in the hospital laboratory and the Central Military Pathological Laboratory.

This narrative is based on the report of the Sprue Research Team. The following medical officers took part in this investigation.

Lieut.-Colonel K.D.Keele, RAMC, Officer-in-Charge, Medical Division, No. 3 IBGH.

Major D.A.K. Black, RAMC, Officer-in-Charge, Biochemical Department, Central Military Pathological Laboratory.

Major R.F. Clutton, RAMC.

Major L.P.R. Fourman, RAMC.

Captain J.P. Bound, RAMC.

The names of other personnel of the team and persons associated with these investigations will be found in the Medical Directorate, Army Headquarters *Report on Sprue in India*.

MAIN OBJECTS OF INVESTIGATION

The main objects of the investigation were :—

(i) to establish further understanding of aetiological factors by collecting the clinical data at the commencement of the disease, and to clarify its natural history particularly in the interpretation of the significance of its varied symptomatology ;

(ii) to find out the state of fat absorption under controlled conditions in the disease ; and

(iii) to ascertain the therapeutic effects of liver and other substances under clinical laboratory control.

CLINICAL DATA

Although many clinical studies of tropical sprue have been published, they have dealt almost entirely with the disease as seen in Europeans of long residence in the tropics, or who have returned to temperate climates before coming under close observation. The patients investigated differed notably from the classical sprue in that practically all acquired the disease within three years of reaching India and in many cases, within a year. The duration of symptoms, before observations were made, was in most cases under six months. This gave the opportunity of observing the early symptoms and the conditions under which they developed. The grouping of symptoms into early primary and later secondary phases has resulted from this aspect of study.

Clinical investigations such as barium meals, fractional test meals and blood counts were done as opportunity permitted. Though limited in their scope, such observations become important when taken in conjunction with the other clinical and biochemical aspects of the work.

FAT ABSORPTION

While the presence of an increased amount of fat is characteristic of the sprue stool, increased fat excretion cannot be detected with certainty by determining the percentage of fat in random samples of single stools, nor can the progress of a case be followed by this means. Therefore, the dietary intake of fat was controlled and total specimens of stool were collected over three or four day periods in sequence. This basic information on fat absorption was supplemented by chylomicron counts and blood fat curves in selected cases. The fat absorption with the absorption of other substances such as glucose and iron was also compared. Observations on electrolyte and nitrogen metabolism and miscellaneous biochemical observations have also been made later in this chapter.

THERAPEUTIC TRIALS

Therapeutic trials were carried out from an empirical aspect to determine a practicable method of sprue therapy, and from the viewpoint of aetiology since the success or failure of substances in treatment enables some conclusions to be drawn as to pathogenesis. The main body of work concerns liver therapy. Here the chief emphasis has been

on defining the manner in which it helps the sprue patient and the aspects of the sprue syndrome which are not affected by liver treatment. A small number of trials were made with pure B complex vitamins, vegemite, glycerophosphate and sulphaguanidine. The success of diet therapy without the addition of any of the above agents was also studied. No attempt has been made here to give a comprehensive review of the mass of literature on tropical sprue. Much of the older literature deals with discarded theories, and a review of sprue literature by Stannus (1942) is already available. The literature directly relevant to the work done in this investigation is covered most conveniently under the separate headings of this chapter.

The clinical section is based upon experience gained from two series of patients. The first consists of more than 600 cases, which were seen in various parts of India during 1943-44, where special laboratory facilities were not available. Observations on these cases are, therefore, limited to aetiological and other clinical features only. For convenience, this series will be referred to as A. 600.

The second series of 80 patients comprises those who have been under investigation since June 1945, by the research team. The investigations on fat absorption were carried out on 25 cases of this series and the remainder also were investigated in greater detail than the cases of series A. 600. This second series will be referred to as B. 80.

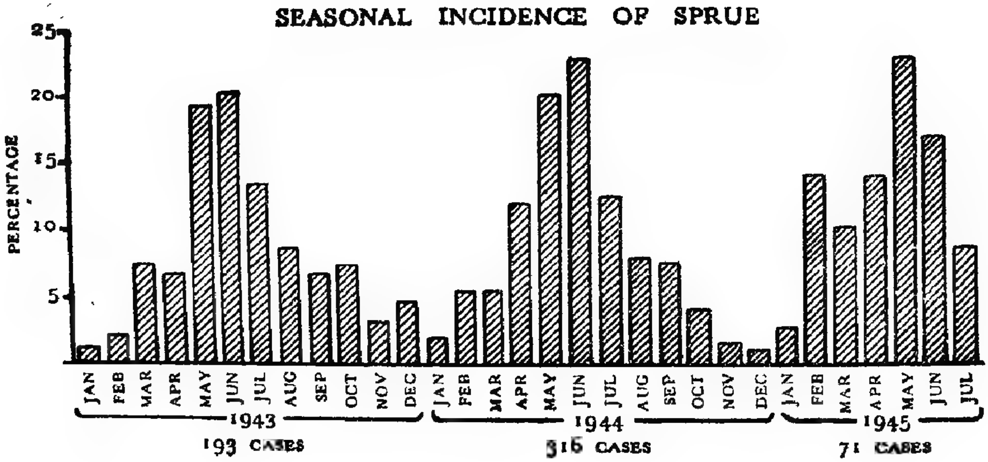
CLINICAL INVESTIGATIONS

AETIOLOGICAL FACTORS IN SPRUE

Seasonal Incidence : In 1943, 1944 and 1945, the incidence of sprue was minimal in the cool months of November, December and January, and increased to a pronounced maximum in the hottest months of May and June. Thereafter the incidence fell rapidly in the monsoon period (Graph 1). This seasonal variation applied to all parts of India and Burma.

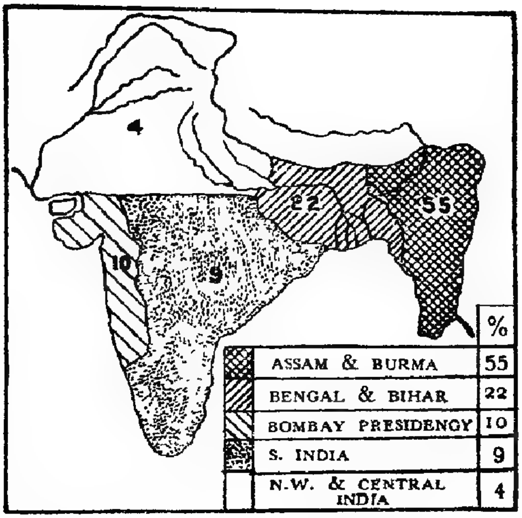
GRAPH 1

SEASONAL INCIDENCE OF SPRUE



GEOGRAPHICAL DISTRIBUTION

The geographical distribution of cases is shown in the following map. It will be seen that 55 per cent. of cases arose in Burma and Assam, and another 32 per cent. in the comparatively small areas of Bengal and Bihar, and the Bombay Presidency. Until the proportion of troops in these areas to those in all India and Burma is known, no inferences can be drawn from these figures.



GEOGRAPHICAL DISTRIBUTION
OF 520 CASES IN 1943-45

Within a climatic zone, sprue is regional. Three localities in particular produced many cases as the tide of war passed through, or came close to them. These were Imphal (13 per cent. of all cases) in the hills, Chittagong (8 per cent.) on the coast near the Ganges delta, and Meiktila (3 per cent.) in the plains of Central Burma.

DURATION OF SERVICE IN INDIA BEFORE THE ONSET OF SPRUE

The maximum incidence in 554 cases occurred after one to two years' service in India.

TABLE I

Duration of service in India before the onset of sprue—Percentage of cases.

Duration of service in India	Percentage of cases
6 months or less	10
6 months to 1 year	16
1 to 2 years	44
2 to 3 years	25
Over 3 years	5

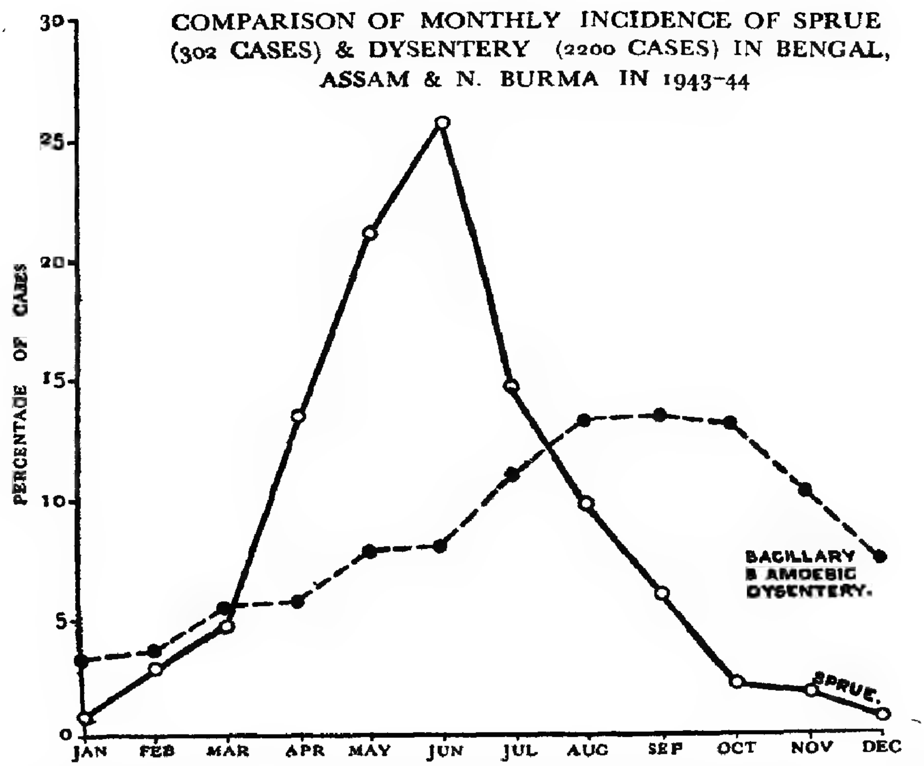
This incidence contrasts with that of classical sprue, which is associated with long tropical residence.

RELATION TO OTHER DISEASES

Dysentery : There has for long been a suspected relationship between sprue and dysentery. The following observations on series A,600 clarify the issue :—

A comparison of the seasonal incidence of sprue and dysentery (amoebic and bacillary) in the same region over the same time is shown in Graph 2. All cases of both diseases were drawn from Assam, North Burma, and Bengal during the years 1943-44. It will be seen that the incidence of sprue precedes that of dysentery surprisingly clearly, in a manner that it shows to be very unlikely that sprue commonly follows an attack of dysentery. The relation to chronic or relapsing dysentery is, of course, not to be derived from such cases.

GRAPH 2



The incidence of dysentery preceding sprue (23·6 per cent.) is shown in Table II. In 16·7 per cent. of cases dysentery had occurred more than one month previously. In 6·9 per cent. it had occurred within one month of the onset. In 340 control cases, the incidence of dysentery in three years' service was 20·8 per cent. The incidence is not significantly high in those with sprue.

TABLE II

Incidence of dysentery preceding sprue (525 cases) and in 340 control cases.

Dysentery	More than one month before onset of sprue (Percentage)	Within one month of onset of sprue (Percentage)	In control cases (Percentage)
Bacillary	8·0	2·5	6·6
Amoebic	5·1	3·8	6·8
Bacillary and amoebic ...	1·7	0·2	2·4
Clinical	1·9	0·4	5·0
Total	16·7	6·9	20·8

In individual cases, a close relationship is sometimes found to exist between an attack of amoebic or bacillary dysentery and the sudden passage of typical 'sprue stools' with the development of the full syndrome. It is probable that the effect of dysentery is nonspecific in activating the latent syndrome.

In a few cases who have had repeated attacks of dysentery, steatorrhoea may come on insidiously with variable development of the sprue syndrome.

Giardiasis : The occurrence of diarrhoea with pale stools in people infected with *Giardia lamblia* is well known. In series B. 80, six cases had giardiasis before admission to No. 3 IBGH and in two cases with mild attacks of diarrhoea, the organism was found in the stools. In these eight cases, the organism disappeared spontaneously or after a course of mepacrine, without altering the course of the sprue.

Malaria : A group of 87 cases labelled malnutrition drawn from the Chindit Force in June and July 1944 were found to include 52 patients with the syndrome of sprue. These cases were seen under circumstances that rendered investigation incomplete, but glossitis with diarrhoea, pale stools, flatulent dyspepsia and marked emaciation were present. Fat analysis of stools in 15 cases showed 12 with faecal fat over 30 per cent. Malaria was found clinically and by positive blood-slide in 42 per cent. Response to sprue therapy in many was unsatisfactory, but improved dramatically after malaria had developed and been treated. This effect of malaria and/or anti-malaria therapy on the sprue syndrome, in these cases, was repeatedly demonstrated. If sprue is present, concomitant latent malaria undoubtedly exacerbates it.

Subacute Hepatic Necrosis : Though subacute hepatic necrosis is not common, several instances of the condition exhibiting the sprue syndrome have been seen at a time when jaundice was absent ; bile pigment was absent in the urine but present in the faeces. The sprue symptoms, including the glossitis and steatorrhoea, improved as the liver diminished in size.

DIET

In series A. 600 a large number of troops, including all those from the Chindit Force, developed the sprue syndrome on 'K' rations. The rest were on field service rations, or the basic ration scale, which was introduced in 1944. The course of events was remarkably constant in men from the Chindit Force. For one week the diet was well taken. Then anorexia of increasing degree supervened followed by diarrhoea two weeks later. Sore tongue appeared after about six weeks on the diet. In some cases, the anorexia became so extreme that the man vomited whilst attempting to eat.

In series B. 80, sixty-three were on the basic ration scale, although in thirty-six of these the ration was supplied almost entirely in the form of tinned and dehydrated foods. Another twelve were on 'K' or compo rations, or a combination of the two. The remaining five form an interesting group in which the onset of sprue coincided with a change from tinned foods to an ordinary or convalescent diet with a good proportion of fresh food.

The approximate composition of these diets is :—

Ration	Calories	Carbohydrate	protein	Fat
Basic ration scale ...	4,000	530 g.	120 g.	155 g.
'K' or compo rations ...	3,200	430 g.	100 g.	130 g.

The vitamin content of all the diets was adequate by accepted standards.

In cases who were closely questioned as to feeding habits, irregularity of meals was not a prominent feature.

RACE AND COMPLEXION

Racial selectivity of sprue is said to be according to pigmentation. The darkest negroes apparently are not affected at all. The incidence amongst Indians is very low while the brunt of incidence falls on Anglo-Indians and Europeans. It is undoubtedly true that Indian troops developed the full syndrome of sprue during the war, though difficulty in diagnosis increased by the commonness of malnutritional anaemia. In British troops, though there was no difference in incidence between dark or fair, it was the latter who provided the great majority of severe cases. No cases were seen amongst Jews.

THE CLINICAL PICTURE OF SPRUE

From the year 1943 to the end of the war, the clinical picture of sprue has differed from that of the classical description of the disease. A brief outline of the clinical types will show clearly where this difference lies.

CLASSICAL SPRUE

This occurs after long residence in the tropics. In series A. 600, ten cases were seen in regular soldiers mostly officers, who have not been included in full investigations. In these patients there was a story of dyspepsia and intermittent diarrhoea over several years, with intervals of months or years between attacks. Sore tongue had been transient. Asthenia and loss of weight, slight at first, had been intermittently progressive until both were marked. Pale stools noticed at first from time to time had ultimately become constant. Such officers may have been investigated in hospital more than once, and discharged symptom-free. On examination most cases showed marked emaciation, smooth tongue, achlorhydria probably histamine-fast, distension, diarrhoea with pale fatty stools and varying degrees of macrocytic anaemia. Response to treatment was poor.

ACUTE SPRUE

This term has been used to describe the great majority of cases of both series, which commenced symptoms of sprue, within two to three years of arriving in India and had reached stage of hospitalisation and invaliding within one to two years of the onset. They show, therefore, both an early onset in the tropics and a rapid course in comparison with the classical cases outlined above. This course may consist of repeated mild relapses of the condition or may quite suddenly progress into a severe form in which dehydration of a dangerous degree supervenes.

Acute Sprue (*Mild*) : This group comprised nine out of ten of all cases. The usual story was as follows :—

' The young BOR within a few weeks of arrival in India, has found himself on jungle training. During this time, he has had attacks of diarrhoea, and perhaps one or two bouts of fever. After this he has been sent to Assam and become involved in the fighting anywhere between Imphal, Meiktila down to Rangoon. During this period, rations have been for the most part plentiful. Even during periods where supply by air had been the only possible route, shortage of rations was rarely prolonged. After periods of a few weeks to some months on such rations, (particularly round Meiktila) diarrhoea has developed, often accompanied by anorexia and vomiting, with marked weakness. Soreness of the tongue later appears with distension and flatulence. The stools may or may not be pale (most are lost in pit latrines). Rapid improvement occurs on hospitalisation with a diagnosis of clinical dysentery, with or without sulphaguanidine therapy ; diarrhoea returns soon after he resumes duty ; the tongue becomes sore again, and the stools pale and bulky. He is again admitted to hospital. As yet, he may not have lost much weight. On hospital diet the tongue clears up, stools regain colour, and by the time he reaches a base hospital there is little abnormal found. Here he may return to duty on a lower medical category. After a few more weeks he again relapses, and again is admitted to hospital, where he makes rapid improvement even after stool fats have shown some rise in the accepted

normal values. This cycle may continue until further relapse results in his being boarded back to Poona, whence, looking very fit he has been evacuated to England '.

Acute Sprue (*Severe*) : Either from the onset or at some later period, the picture as outlined for a mild case may change into the syndrome of severe sprue. This is characterised by the signs of dehydration. Diarrhoea of moderate to marked intensity is invariably present. Sometimes, 15 to 20 pale liquid stools per day are passed. Anorexia and vomiting are constant owing to which dietary intake of fat is low—stool fat is, therefore, not markedly raised at this time. Laxity of skin, gross and rapid emaciation, hypotension, soft eye balls, dry tongue, often showing signs of glossitis, are present. Within a few days the patient becomes drowsy, the hypotension persists with extreme weakness and prostration and he becomes semi-comatosed. In spite of these advanced signs, response to parenteral liver therapy is obtained, and such cases, though showing 60 to 70 lbs. loss of weight, have not died but returned to normal weight in four to five months on such therapy.

STEATORRHOEA WITH NO GLOSSITIS (INCOMPLETE SPRUE OF MANSON-BAHR)

Diagnosis in this group of seven cases from series B. 80 has been based on symptoms of anorexia, vomiting, diarrhoea with pale stools and weakness, with a faecal fat greater than 30 per cent. Loss of weight of 20 lbs. or more was present in all. The notable features about these cases have been :

(i) Duration of only one to two months in all seven cases before hospitalisation and treatment.

(ii) All cases occurred during the hot season between March and June. Response to dietetic treatment was good in all but one.

In two further cases with similar symptoms and steatorrhoea both commencing in May, but with only 5 lbs. loss of weight, response to diet therapy alone was rapid and satisfactory.

In the earlier series A. 600, 3·6 per cent. showed this form of the sprue syndrome with good response to diet therapy.

GLOSSITIS WITHOUT STEATORRHOEA (LARVAL SPRUE OF MANSON-BAHR)

In the series A. 600, faecal fat of less than 30 per cent. was found in 20 per cent. of cases. On analysing this series it was suspected that repeated fat analysis would reduce this percentage considerably. Such was the case in the second series (B. 80) in which only six (7·5 per cent.) were found with faecal fat persistently less than 30 per cent. in the presence of pale stools. In these cases, single-stool fat analysis was used, two to three estimations being performed. Four cases were on a fat diet of 85-95 g. daily before the fat analysis.

This type of cases occurred in men who had been out in India longer than the average, i.e. two to three years (one case eight and a half years). Loss of weight was in all between 20 and 30 lbs. The glossitis had persisted

for two to three months before admission, with anorexia, flatulence and distension, and intermittent diarrhoea of three to five pale loose stools daily. Response to sprue diet with nicotinic acid and cooked liver by mouth was not satisfactory. Though the tongues became normal in about one month, and the stools formed and coloured, flatulence and distension persisted and gain in weight was only about 5 to 10 lbs. In these cases there was no anaemia and fractional test meals in all showed normal acid curves.

Prognosis does not appear very good in this type of cases. Tendency for the glossitis to relapse is marked, and weight remains low.

TROPICAL SPRUE IN DYSPEPTICS

A group of six cases in series B. 80 was found in which dyspepsia had been a disability for years in England. Two specifically attributed their chronic dyspepsia to fats, and one more volunteered that for one year he had passed pale stools intermittently. All were found to have steatorrhoea within three months of reaching India. One commenced chronic diarrhoea in the Red Sea on the way out, and another immediately on arrival. The possibility that these men had steatorrhoea in England has to be considered.

SYMPTOMATOLOGY : THE SPRUE CYCLE

The main points in symptomatology are illustrated in Graph 3 and Table III.

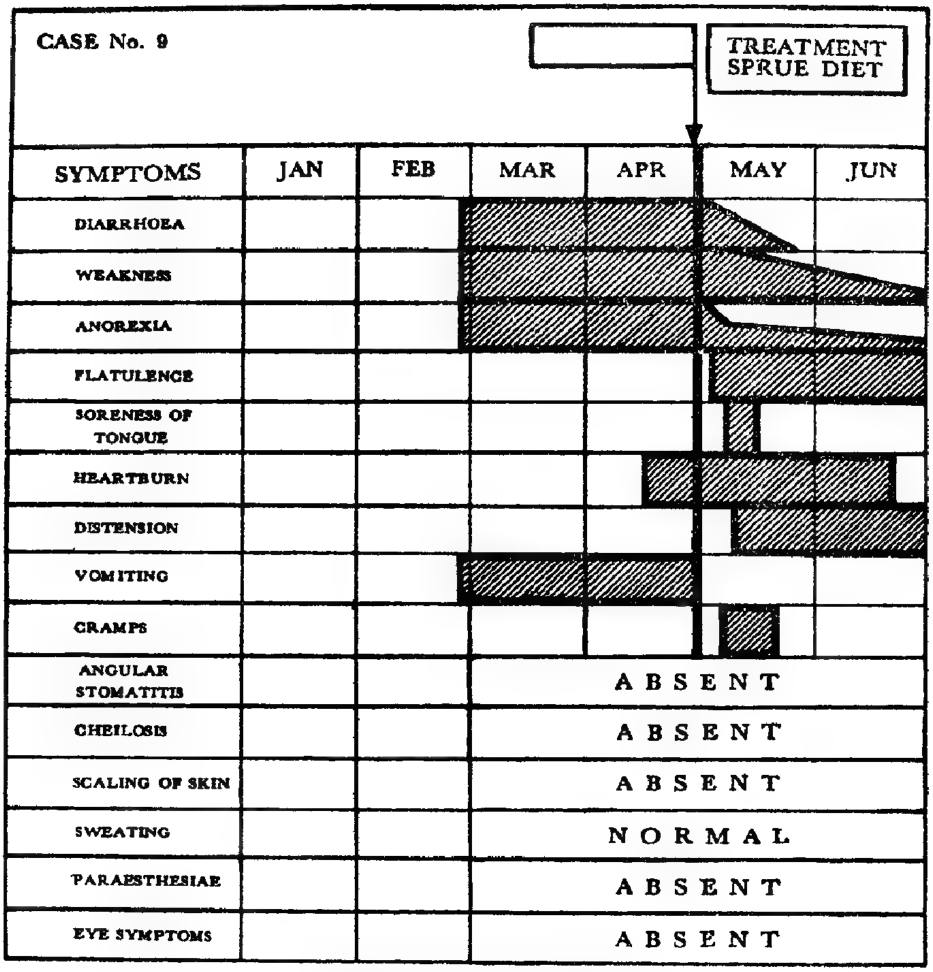
Graph 3 is that of case No. 9 of series B. 80. It shows clearly the grouping of symptoms into two phases which were found well marked in some 85 per cent. of cases.

Symptoms of onset consist of anorexia, diarrhoea, vomiting, weakness and loss of weight. Diarrhoea is often but not always first, the remaining symptoms following quickly form a symptom complex that is clear-cut and persists from a few weeks up to two to three months, before a second group of symptoms develops. The chief sign of the second phase is glossitis which does not occur in the initial phase of onset, appearing only after about six weeks in most cases. With glossitis and cheilosis appear other signs, of which abdominal distension is the most prominent. At the time these appear, flatulence and scaling of the skin increase in incidence and severity. As this second group of symptoms develops, those of onset disappear—appetite returns to normal or to voracity, diarrhoea diminishes or changes to constipation, weakness becomes less intense, and weight loss ceases or tends to increase.

In an untreated patient this remission of diarrhoea and return of large appetite results in increase in food consumption, which within a few days is followed by a return of diarrhoea with the other symptoms of relapse. With relapse the glossitis and distension may decrease but weight is lost again.

This cycle may continue indefinitely with progressive loss of weight to malnutritional levels.

Graph 3.



TYPICAL CLINICAL PICTURE IN A CASE
OF ACUTE SPRUE (MILD)

The group of symptoms associated with onset and relapse are similar. They have, therefore, been described together as 'symptoms of onset or relapse'.

The second group of symptoms characterised by glossitis and distension, etc., have been grouped as 'symptoms of remission', since during this phase the patient has increased appetite, gains weight and shows general clinical improvement.

Table III shows the change of incidence of symptoms within two weeks of commencement of treatment. From the figure it will be seen that though the symptoms of relapse except weakness rapidly diminished in hospital, those that have been grouped as the symptoms of remission increased markedly in incidence after admission. At first it was not understood why after admission and treatment, patients should apparently

deteriorate, but on observing relapses which occurred it was noticed that the sequence—diarrhoea, anorexia and loss of weight was often followed by sore tongue and increase of distension when the diarrhoea stopped, and appetite improved, after which weight again increased. Such a miniature cycle might be completed in a week.

On a large scale, this cyclic period was found in those cases which came into hospital in relapse and responded to diet therapy. Glossitis produced in this way occurred at the change-over from relapse to remission and lasted from a few days to two to three weeks, often clearing on diet therapy alone.

TABLE III

Change in incidence of symptoms after diagnosis and commencement of treatment.

Symptoms	Incidence of symptom before diagnosis Percentage	Incidence of symptom after diagnosis Percentage	Change in incidence Percentage
Diarrhoea	99	69	—30
Disturbance of appetite	91	79	—12
Vomiting	44	38	— 6
Cramps	14	15	+ 1
Weakness	94	98	+ 4
Heart burn	60	65	+ 5
Angular stomatitis ...	9	18	+ 9
Cheilosis	5	24	+19
Scaling of skin	9	31	+22
Flatulence	73	96	+23
Soreness of tongue ...	61	90	+29
Distension	60	95	+35

SYMPTOMS OF ONSET OR RELAPSE

Anorexia: This symptom usually commenced shortly after diarrhoea and was accompanied by weakness. It was more marked in the evening. Often the only meal of the day to be enjoyed was breakfast. Anorexia may be very marked. One of the cases admitted to No. 3 IBGH had been for months diagnosed as anorexia nervosa. Anorexia increases with the severity of the relapse.

Vomiting : Though common, this symptom is rarely severe in degree. It was most commonly observed in those patients who were worried by gnawing hunger and whose appetite disappeared after a few mouthfuls of food. In such cases the rest of the meal was virtually forced down. Half an hour later the hunger usually returned. In case of severe relapse, it may seriously increase the dehydrated state of the patient.

Diarrhoea : This, almost constantly, was the mode of onset. The diarrhoea may be violent with colic and urgency. Stools were often coloured at first, becoming pale after a variable period. In the same way, there was a variable period between the onset of diarrhoea and that of weakness, anorexia and flatulence. Stools may be frequent, 15 to 20 per day. This and the temporary response to sulphaguanidine often led to a diagnosis of 'clinical dysentery'. Later the pale liquid stools became firm, as remission occurred, and glossitis appeared. Whilst the stools were loose, weight was not gained.

Asthenia : This symptom was found remarkably constant and prominent in the histories of both series of cases. The symptom occurred early, often at the commencement of the diarrhoea. In a group of cases arising near Meiktila it preceded all other symptoms by some weeks. Such asthenia is well illustrated in the case of a patient who had to drag himself upstairs by hauling on the hand-rail. Dyspnoea, palpitation and other symptoms of effort syndrome were not present.

Loss of Weight : Loss of weight is difficult to assess in the tropics owing to the common adjustments that take place in normal men. In 54 healthy men, change in weight after six months in India was found to be as follows :—

Loss of weight in 33 (61 per cent.) averaging 8·8 lbs.—range up to 18 lbs.—gain in weight in 14 (26 per cent.) averaging 5·4 lbs.—range up to 15 lbs.—no change in weight in 7 (13 per cent.).

Normal variation of weight in India is approximately ± 10 per cent. of the body weight in England. In 47 cases which later developed sprue, change in weight whilst they were in good health was as follows :—

Loss of weight in 18 (38 per cent.) averaging 8·5 lbs.—range up to 19 lbs.—gain in weight in 15 (32 per cent.) averaging 6·9 lbs.—range up to 14 lbs.—no change in weight in 14 (30 per cent.).

There is thus no evidence of the potential sprue cases having lost weight unduly in India before the onset of the disease. The degree of loss of weight on admission to hospital in the series A. 600 cases was approximately 25 per cent. of their English weight. The most severe emaciation seen was in a patient, whose normal Indian weight was 156 lbs. and who was admitted weighing 85 lbs.

TRANSITION FROM RELAPSE TO REMISSION

It has been stated that when a patient enters remission the symptoms of relapse diminish and disappear. This happens in a clear-cut manner when patients enter hospital in relapse and respond at once to treatment (63 per cent. of cases treated by diet alone). In some, however, the transition is slow. Symptoms of relapse diminish but do not disappear, instead become variable, whilst symptoms of remission also vary. In such a patient, appetite varies from day to day—even from hour to hour, stools vary, a period of mild diarrhoea followed by a day or two of constipation. Distension and flatulence are distressing and under these conditions weight is not gained, or rather, a few

pounds slowly gained, are rapidly lost again. Glossitis like other signs is persistent though variable during such a period.

Such static cases can be turned into full remission phase with parenteral liver therapy when after one week, the signs of relapse disappear whilst distension increases, appetite returns, and weight is gained. With remission induced by liver, glossitis is much less marked than with remission on diet alone.

GLOSSITIS, CHEILOSIS AND ANGULAR STOMATITIS

Since the word 'sprue' connotes sore mouth and tongue, it is of importance to note its place in the 'symptoms sequence' described.

Glossitis was present in over 90 per cent. of the cases treated. It will be seen from Table III that it was present in only 61 per cent. of patients before treatment. The increase in incidence occurred on hospital diets either in those put on a sprue diet because of a discovered steatorrhoea, or on 'ordinary' diets. Thus, many cases diagnosed as steatorrhoea, later, on treatment produced the necessary evidence to change that diagnosis to sprue. Glossitis is thus not an early symptom in many cases. The average duration of diarrhoea in all cases before the onset of glossitis was 3·2 months.

Glossitis appears at the beginning of remission. In fact, it seems to mark the change from relapse to remission. In those cases where it has developed in hospital where observation of associated symptoms has been possible, it has been noticed to coincide with the diminution of the signs of relapse and to last about two weeks if sprue diet is continued during which time appetite improved, distension became more prominent, and stools firm pale and bulky. It disappeared without any addition to the diet therapy, and at this time further gain in weight of the patient was noted. Such a patient usually continued to improve, and returned to normal weight. In most cases, there was eventually no steatorrhoea, but this was often most marked at the period when glossitis slowly diminished and later when weight was gained. In some, however, even with normal weight, steatorrhoea persisted. In cases regaining weight in this manner, glossitis did not return unless there was a relapse at the end of which it re-appeared in a similar transient fashion.

That glossitis results from simple deficiency of the B group vitamins is known. From this point of view, the diets of 66 cases before and at the time of the onset of glossitis were ascertained with the following results :—

Diet at onset of glossitis (66 *cases*)—

(i)	Army basic ration scale ...	43 cases (64 per cent.) (21 of these were on tinned and dehydrated rations).
(ii)	'K' rations	5 cases (8 per cent.).
(iii)	Hospital ordinary diet ...	9 cases (14 per cent.).
(iv)	Sprue diet	9 cases (14 per cent.).

In the case of diets in hospital, glossitis usually came on within two weeks. But these diets as a whole do not suggest insufficient provision of either calories or vitamins. However, with previous history of anorexia and diarrhoea, it is quite possible that a conditioned deficiency had been produced.

The Appearance of the Tongue : In nearly all cases the glossitis was marked by a bright red tongue, sometimes oedematous, and in the early stages, very sore. Smoothness develops quickly, at first due to sub-epithelial oedema with swollen tight-packed papillae. Only later is true depapillation present. Such tongues alter rapidly from day to day. Improvement from deep red to normal is often observed in less than a week on diet alone.

Fissures have not been a prominent feature. Congenital fissures have been seen to deepen and ulcerate in their depth. Superficial acute fissuring responds to diet therapy as quickly as the other features of glossitis. Such fissuring and the typical painful small ulcers of mouth and tongue occur at the height of glossitis.

The magenta tongue of so-called riboflavin deficiency was seen on three occasions. In none was this appearance altered by riboflavin therapy, parenteral or by mouth.

In patients whose condition continually oscillates from relapse to remission, the tongue changes persist over long periods. With each bout of active glossitis there is soreness and hyperaemia. If this recurs frequently before the depapillated tongue has had time to restore its normal structure, then the atrophic smooth tongue appears.

With successful treatment this cycle is stopped. The large majority of tongues returned to normal appearance remarkably quickly in two to three weeks. Nevertheless, there is often a period of one to two weeks during which the tongue is not sore but shows a smooth tip and sides, and in some cases this smoothness persists for weeks. In all the cases admitted to No. 3 IBGH, however, the tongue returned to normal before discharge from hospital. No correlation between the glossitis and gastric acidity could be found.

Angular stomatitis and cheilosis were less common findings, but they too more than doubled their incidence after admission to hospital—from 9 per cent. to 18 per cent. with angular stomatitis, and from 5 per cent. to 24 per cent. with cheilosis. Cheilosis varied with the glossitis ; angular stomatitis developed after glossitis, and responded more slowly to treatment. In several of these cases, dentures had been worn so that failure to achieve results with parenteral and oral riboflavin bears doubtful significance.

ABDOMINAL DISTENSION

In the onset and relapse phase of sprue, distension of the abdomen is usually absent. This has been particularly noticeable in all cases admitted to No. 3 IBGH with acute severe sprue. Equally remarkable has been the appearance of distension after treatment, coincident with

cessation of diarrhoea and vomiting and return of appetite. In this context it is a welcome sign.

In most of the other cases it did not appear for two to three months, often at the same time as glossitis, with the cessation of diarrhoea. Unlike glossitis, it persists for weeks or months during remission. It appears to be more closely related to steatorrhoea than any other change, but even this relationship is loose for it has persisted after the stools have become normal in several cases, and conversely steatorrhoea can persist without distension.

The mechanism of production of abdominal distension is difficult to understand. Barium meals did not show megacolon or exceptional flatulence in cases with marked distension. It is aggravated by increasing the diet unwisely and is in such cases perhaps of value as a warning that further increase in diet will precipitate relapse.

Considering that it is probable that distension is related in some way to absorption from the gut, its absence was taken as an important criterion of complete remission.

FLATULENCE

This common symptom occurs to varying degree during the phase of relapse with diarrhoea, but it is increased after hospitalisation from 73 per cent. to 96 per cent. of cases. This increase coincides with an increase of upper abdominal flatulence with belching and heartburn, which appears more marked during early remission.

SKIN CHANGES

These changes apparently became more marked after admission to hospital. At first it was considered that the increase might be merely a matter of closer observation but further experience made it clear that scaling of the skin with loss of hair are accentuated when the remission phase is entered. Various terms of description have been used by dermatologists to interpret this scaling. However, the term 'scaling of the skin' appears to be the most appropriate. The features of hyperkeratosis, parakeratosis and follicular hyperkeratosis have been present in varying degree, often lasting about one month and then subsiding as remission progresses. The hair fall out extensively and is general, the size of scale varies from fine branny desquamation to plaques of the size of a finger-nail, like those seen in ichthyosis. Pigmentation of the skin was not a prominent sign. Skin signs associated with riboflavin deficiency were not seen.

MISCELLANEOUS SYMPTOMS UNRELATED TO REMISSION AND RELAPSE

CRAMPS AND TETANY

In series A, 600, cramps occurred in calves and thighs in 25 per cent. One case developed tetany. In the series B. 80, calves and thighs were almost the only sites in the 14 per cent. of cases affected and the

symptom usually improved rapidly in hospital. In one case, generalised tetany developed with a total blood calcium 9 mg. per cent. This case simultaneously showed evidence of an acute myopathy affecting the muscles of the shoulder girdle, particularly the deltoids and the extensors of the neck, with complete loss of power. No sensory changes were present, and at the time there was generalised loss of reflexes. The patient who had been dangerously ill was responding after six days' parenteral liver therapy.

The myopathy and the tetany subsided in one week without further therapy. This instance strongly reminds one of the myopathic type of case of non-tropical sprue described by Thaysen.

NEUROLOGICAL SIGNS

Paraesthesia was absent in all cases. Neurological examination revealed no evidence of motor or sensory change, but tendon reflexes diminished or were absent in severe cases, as described above in one case, in the presence of tetany. Mental changes have not been seen.

SIGNS OF VITAMIN DEFICIENCIES

In series A. 600, it was noted that the signs of vitamin deficiency states were limited to glossitis, angular stomatitis, and possibly skin changes. In the absence of any evidence of deficient dark-adaptation, the skin changes were considered to be of doubtful relation to vitamin A deficiencies. All these signs cleared remarkably without specific therapy. There were no signs of deficiencies of the fat soluble vitamins D or K, nor of water soluble thiamine or ascorbic acid, and the full syndrome of riboflavin deficiency was not seen.

Observations in series B. 80 confirmed these findings. In these patients, it was noticed that glossitis, angular stomatitis, and scaling of skin appeared more markedly after treatment in hospital, on either ordinary hospital or sprue diet, both probably adequate in nicotinic and riboflavin content.

In No. 3 IBGH wards, on an investigation diet used for purposes of therapeutic control, in which nicotinic acid content was 5 mg. to 10 mg. and riboflavin 3 mg., cases B. 53 and B. 66 showed marked exacerbation of glossitis which cleared in fourteen and ten days respectively without alteration of the diet.

In several instances, patients admitted with glossitis had lost it on this diet without other therapy.

These observations have not supported expectations of relating the glossitis in sprue to simple nicotinic acid or riboflavin deficiency.

It has been noticed that the group of symptoms including glossitis, stomatitis, cheilosis and scaling of the skin occur at the beginning of remission phase. They are preceded by an onset phase of anorexia, vomiting and diarrhoea which may last some months. At onset,

the diets of these patients had been adequate in calorie and vitamin values. If, therefore, the mouth and skin changes are accepted as evidence of vitamin deficiency, it would appear that they are secondary to anorexia, vomiting and diarrhoea in the onset phase of the disease and that they appear most marked at a time when these conditioning factors are removed, i.e. when appetite returns, diarrhoea ceases and tissue demand increases.

At this time at least some of the capacity for absorption and utilisation of food substances by the tissues is restored, as judged by the fact that on a suitable diet weight increases. If the diet is adequate in vitamin content, absorption from the gut improves, and tissue utilisation becomes adequate. Such deficiency symptoms as glossitis might be expected to be transient.

In this connection it is of interest to note that with remission induced by liver therapy, glossitis is never marked and often absent altogether. Such a finding suggests that liver contains factors which specifically prevent the glossitis—factors possibly belonging to the vitamin B group.

It would appear that the symptoms of onset may occur with steatorrhoea, and response to therapy good without glossitis and skin changes ever occurring. Such cases showing steatorrhoea without glossitis comprise the group termed by Manson-Bahr as 'incomplete sprue'. All nine such cases in series B. 80 were of short duration (one to two months). Two had lost only 5 to 10 lbs. in weight ; the others had lost over 20 lbs. in weight. They responded rapidly to diet therapy.

This group of cases suggests that in the early stage of sprue the vitamin deficiency states are not yet developed and remission may occur without any such manifestation.

The incidence of cases of larval sprue (glossitis without steatorrhoea) was 20 per cent. in series A. 600 and 7·5 per cent. in series B. 80. It is probable that even in this small number steatorrhoea had occurred at some time previously.

These patients too had lost 20 to 30 lbs. They differed from the group of incomplete sprue cases in that they had been in India longer than average, but were typical in their symptomatology.

CIRCULATORY CHANGES

Attention has been given to two aspects of the circulatory changes in sprue—cardiac size and hypotension.

Cardiac Size : Screening and teleradiograms of the heart show that heart size is always within normal limits. It is questionable whether a pathologically small heart can exist and so criteria upon which such a small heart can be diagnosed have not received as much attention as those for cardiac enlargement. It is, therefore, only possible to state that the heart in sprue is 'small normal' as judged by screening, cardiothoracic ratio and transverse diameters, in ten cases.

Hypotension : In series A. 600, 8 per cent. of cases showed hypotension—arbitrarily defined as a blood pressure below 100/70 mm. Hg. In series B. 80, such hypotension has been found in 18 cases (22·5 per cent.).

Dehydration : Twelve acute severe sprue cases showing all the symptoms of relapse with dehydration had hypotension. This persists in some degree usually for about one month after the dehydrated condition had been overcome. In three cases only, the blood pressure returned to normal within a week of treatment. A group of ten such cases had been further studied regarding electrolyte changes.

Hypotension without Dehydration : In six cases hypotension appeared in mild cases without any acute dehydration phase. It lasted only two to four weeks, improving with the patients' weight and general condition.

In such persistently hypotensive patients the low blood pressures were usually stable, and were neither postural, nor associated with vasomotor symptoms.

Barium Meal

Barium meal investigations were carried out on nine cases. The results are summarised in Table IV.

Table IV

Summary of barium meal findings in nine cases of sprue.

Case	Weight change	Stomach emptied	Mucosal pattern	Region of gut reached in 1 hour	3 hours	6 hours	Marker time
1 E. B.	...	6 hours	Bolus ++	Caecum	Descending colon	Sigmoid colon	13 hours
1 E. B.	++	6 hours	Normal	Ileum	Caecum	Ascending colon	41 hours
2 H.T.	0	3 hours	Bolus +	Ileum	Ileum	Ascending colon	8 hours
3 Mc.K.	0	3 hours	Bolus +	Ileum	Ileum	Hepatic flexure	31 hours
4 R P.	0	3 hours	Bolus slight	Ileum	Ileum	Ascending colon	...
5 S.C.	0	3 hours	Normal	Ileum	Ileum	Ascending colon	47 hours
6 S.H.	+	1 hour	Normal	Ileum	Caecum	...	56 hours
7 J.K.	+	1 hour	Normal	Ileum	Ileum	Splenic flexure	23 hours
8 V.M.	++	6 hours	Normal	Ileum	Splenic flexure	Splenic flexure	22 hours
9 F.H.	—	6 hours	Normal	Hepatic flexure	Splenic flexure	Sigmoid colon	24 hours

In all cases the patients were screened and filmed standing. Films were taken using 0·12 seconds exposure with 80-85 K.V. at fifteen minutes, thirty minutes, one hour, three hours, six hours and twenty-four hours. Four ounces of barium sulphate in watery suspension, free of fat, was used. Each case was given an iron marker consisting of ferrous sulphate grains $7\frac{1}{2}$ in capsule, at the commencement of the meal, to ascertain the rate of passage through the bowel, as it is not easy to detect barium in the pale sprue stool. In Table IV, gain or loss of weight occurring up to the time of examination was noted, as this feature closely reflects the general condition of the patient, indicating whether he is in relapse or remission. Only one patient (case 1EB) was X-rayed whilst in the stage of marked relapse.

RESULTS

Stomach emptying time which is often asserted to be prolonged in sprue, was shown to be very variable, from one to six hours, and not correlated with the phase of the disease.

Mucosal pattern was investigated with full awareness of the variability of normal pattern. For this reason, such appearances as 'coarsening of the mucosal folds' were ignored, and almost complete absence of mucosal pattern with gross bolus formation were taken as the criteria of abnormality. Special contrast methods were not available so that finer deviations from normal may well have missed detection.

Case 1 E.B. was the most remarkable of the series. At the first examination this man was in severe relapse with diarrhoea. His weight was 40 lbs. below normal and he was rapidly losing weight; steatorrhoea at the time was 36 per cent. His X-ray showed no evidence of a mucosal pattern, the barium being shown in 15 and 30 minute films clumped into large masses in the jejunum. Screening showed these masses to be firm; they could not be spread by pressure; they appeared static, and not rapidly progressive though this impression was not consistent with the caecum being reached in one hour, and the marker being passed in thirteen hours.

The second barium meal was done one month later. At this time he had gained 20 lbs. on sprue diet and parenteral liver therapy. Distension was then marked, and steatorrhoea two days previously had been 50 per cent.

Cases 2, 3 and 4 also showed bolus formation with little evidence of the feathery distribution of barium. The appearances were less marked than in Case 1. These cases had all been severe. At the time of X-ray they were typical sprue cases showing steatorrhoea of moderate degree. They were all underweight and were also not gaining weight.

Case 5, though static at the time of the barium meal, showed no abnormality of mucosal pattern that could be detected.

Cases 6, 7 and 8 were gaining weight with good appetites. Distension and steatorrhoea were present. Case 8 had been severely ill but was responding very well to liver therapy.

Case 9 was of normal weight at the time of barium meal but steatorrhoea persisted. All the four cases in remission showed apparently normal mucosal patterns.

Motility: Gross variations in rates of passage through the whole intestinal tract and various parts of it occurred, and it would seem that these were beyond the range of normal. With improvement in appetite and gain in weight, the passage of the barium meal slowed down as shown in case 1, and by the fact that in those gaining weight the passage took 23 hours or more.

But this statement does not apply to the rate of passage through the small intestine which remains variable even with improvement of absorption. Case 9 who was chosen by reason of his being of normal weight, practically symptom free, with steatorrhoea only, showed rapid passage of barium to the hepatic flexure in one hour, but the marker was not passed in the stool for 24 hours.

The positive X-ray changes on barium meal examination seen in these sprue cases have been :—

(1) obliteration of mucosal pattern in the jejunum,

(2) bolus formation with aggregation of barium in large lumps and little scatter through the coils of small intestine.

The degree of this change has been found to be related to the severity of the condition. It was more marked when the patient had diarrhoea, anorexia and loss of weight, i.e., he was in relapse phase of the disease.

Hypermotility was present in the relapse phase of the disease, though there was stasis in the jejunum at the same time. This hypermotility diminished in the remission but remained variable.

Flatulence was not a prominent feature in these cases. It certainly had not accounted for the marked distension present in the remission phase of the disease.

FRACTIONAL TEST MEALS

In series A. 600, 66 per cent. of cases showed normal or hyperchlorhydric curves. Lack of histamine prevented assessment of the frequency of true achlorhydria but hypochlorhydric curves were present in 27 per cent.

Series B. 80 showed the following :—

	Normal curves	Hyperchlor-hydria	Hypochlor-hydria	Achlorhydria	
				Apparent	True
Number of cases	29	13	13	6	5
Percentage	44	20	20	9	7

Cases with true histamine fast achlorhydria were all either of long duration i.e., one to two years, or instances of severe sprue. Two produced acid after histamine on a later occasion following parenteral liver therapy. Apparent achlorhydria showed no relation to the severity or duration of the disease.

Hypochlorhydria was associated with diarrhoea, vomiting and flatulence much more commonly than normal or hyperchlorhydric curves. Glossitis was present in 60 to 65 per cent. of these cases at the time of the test meal regardless of the level of the acid curve. It was not more common amongst the achlorhydric group.

Of the barium meal series, which showed bolus formation, case 2 had hypochlorhydria, cases 3 and 4 showed normal curves. In case 1, no test meal could be done.

BLOOD CHANGES

Technique : All investigations were carried out on venous blood drawn without stasis using Wintrobes mixture as anticoagulant.

Haemoglobin was estimated by Sahlis method. 15 g. per 100 cc. was taken as normal.

Erythrocytes were counted in a Neubauer's chamber, the blood being diluted with Hayem's solution in a Hawksley pipette.

Packed cell volumes were estimated using cut down Westergren tubes (Wintrobes tubes were not available). These tubes being graduated 0-100 were found very suitable and gave normal results in control cases. The tubes were spun for $\frac{1}{2}$ hour at approximately 2,500 revolutions per minute and then for $\frac{1}{4}$ hour at approximately 4,000 revolutions per minute. Readings were taken until a constant value was obtained.

Reticulocytes were counted by the Osgood-Wilhelm technique.

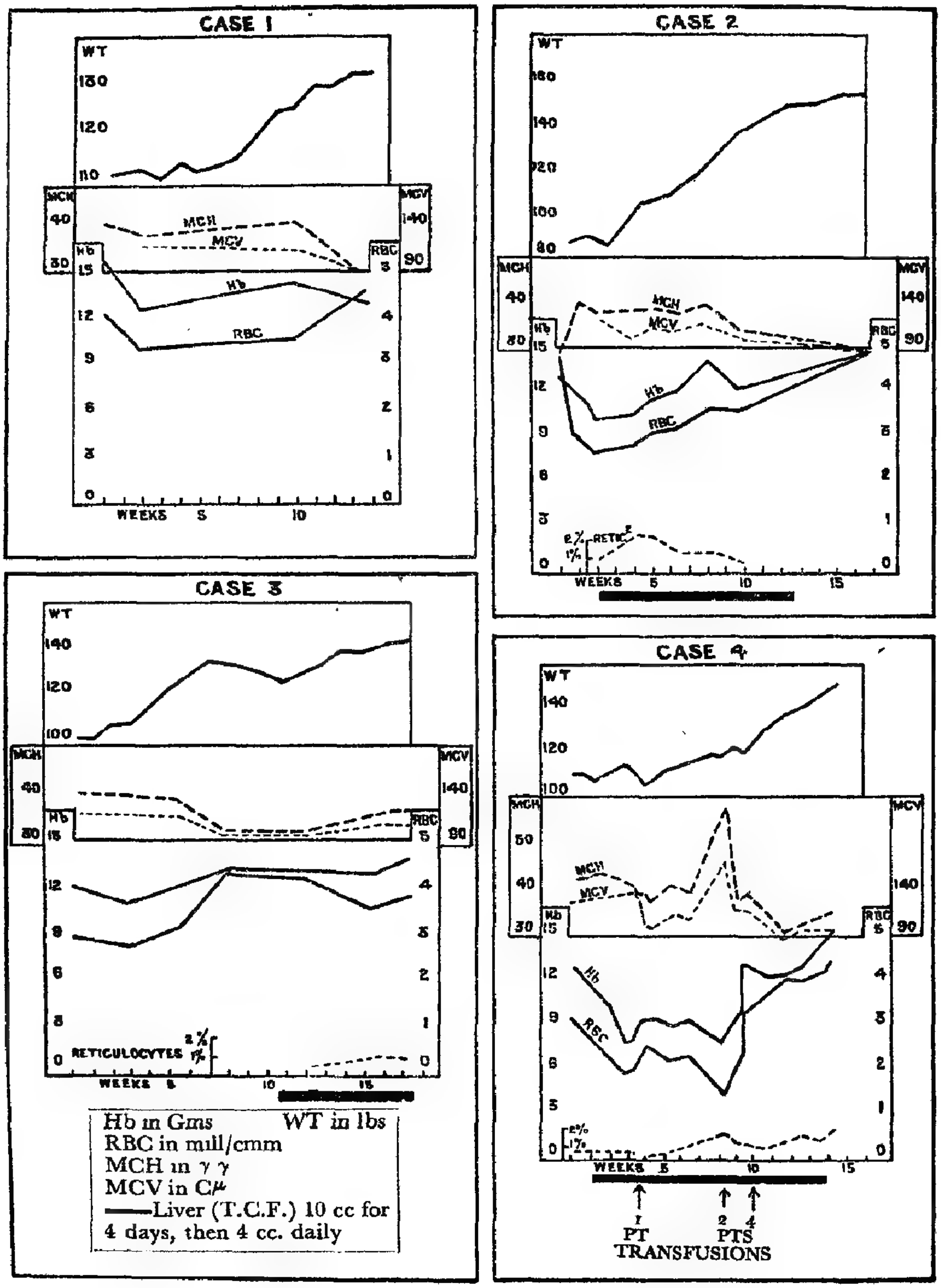
In series A. 600, blood counts were grouped according to the haemoglobin level, and a value of less than 12 g. per cent. was present in only 24 per cent. of cases. At this level, the MCH was minimal (29·577), and variation in haemoglobin in either direction was associated with a rise in MCH. No serial blood counts could be done.

In series B. 80, some cases had repeated counts over periods of many weeks. The charts of four cases typical of the changes in the blood picture on different forms of therapy are shown in Graph 4.

Case 1 shows the response in a case treated by sprue diet only. When first seen, this case, although at his lowest weight, was not dehydrated and had no anaemia but the MCH and MCV were above normal limits. In two weeks a slight macrocytic anaemia had appeared (haemoglobin level 12·2 g. per cent.). As the general condition of the case improved (shown by the weight chart), there was little alteration in the blood picture. It was only at the time when gain of weight ceased as normality was reached that the RBC count rose, and the blood picture returned to normal limits.

GRAPH 4

TYPICAL BLOOD PICTURE IN FOUR CASES OF ACUTE SPRUE



Case 2 was one of acute severe sprue. Although loss of weight was profound (71 lbs.), the blood picture remained normal until the weight was at its lowest, when a macrocytic anaemia developed. The continued drop in the blood count in the second week when an initial rise in weight occurred and dehydration was corrected, is to be attributed largely to dilution of the blood, as the plasma proteins fell from 5·9 g. per cent. in this period. Response to liver therapy was dramatic clinically but improvement in the blood count was slow with persisting macrocytosis, and the maximal reticulocyte response was poor (2 per cent.) and delayed (third week of therapy). As in Case 1, a return to a normal picture occurred only when the weight was nearly normal.

Case 3 initially showed a persisting mild macrocytic anaemia with clinical improvement on diet therapy. He then had a relapse before normal weight had been reached, but the haemoglobin and particularly the RBC count rose and the blood picture became normal. This persisted throughout the period of relapse. The relapse was treated with liver therapy and response was good. In spite of this, a drop in the RBC count occurred and the blood picture again showed a macrocytosis.

Case 4 was also one of acute severe sprue, with a macrocytic anaemia. Response to liver therapy was poor clinically, and the blood count continued to fall. Accordingly in the fifth week, a blood transfusion of one pint was given—a procedure which had always produced a rapid and permanent response in previous cases of progressive anaemia. In this case, the blood count continued to fall. It is noteworthy that this transfusion produced no immediate effect on the count ; this is to be attributed to the clinical improvement (with blood dilution) occurring at the time, following on a period of relapse with dehydration. As the case still failed to respond to usual therapy, two further transfusions of two and four pints respectively were given. After this the blood picture continued to improve and became normal, and clinical improvement was observed.

The rest of series B. 80 showed similar blood changes. They showed in their initial counts :—

A. Macrocytic anaemia (26 per cent.).

B. Normal haemoglobin level and RBC count, but macrocytosis (30 per cent.).

C. Normal counts (35 per cent.).

D. Hypochromic anaemia (9 per cent.).

These later changed in the direction—Group A to Group B to Group C, i.e., from macrocytic anaemia to normal haemoglobin values with macrocytosis, then finally with complete remission to normal counts.

Hypochromic anaemia was uncommon (9 per cent. only) ; all were cases of mild sprue which responded to diet therapy alone. Helminthiasis was found in three instances only—one ascariasis, one strongyloides stercoralis, and one ancylostoma duodenale.

The blood changes in these cases of sprue as exemplified above may now be summarised :—

(i) In the initial phase of the disease the blood count remains normal for a varying period, often until a profound loss of weight has occurred.

(ii) The haemoglobin level and the RBC count then fall, the latter more markedly, and a macrocytic anaemia is produced.

(iii) With clinical improvement associated with remission, a slow improvement in the haemoglobin level and cell count occurs, but macrocytosis persists.

(iv) (a) As the patient approaches a normal weight, the RBC count rises more rapidly, with fall of MCH and MCV, and the blood picture returns to normal.

(b) In a relapse before normal weight is reached, the blood picture improves and may apparently become normal but becomes abnormal again as clinical improvement occurs once more.

(v) In dehydrated patients anaemia often appears unexpectedly slight due to haemoconcentration. Conversely the institution of successful therapy often results in an initial fall in the blood count, as dehydration is corrected.

(vi) Severe anaemia is neither correlated with achlorhydria, nor with the degree of glossitis. It was found that the degree of glossitis is no guide to the severity of the anaemia, but the onset of glossitis often coincides with the appearance of macrocytic anaemia. Both appear during transition from relapse to remission phase. In cases treated with liver, the glossitis is absent or slight.

(vii) Liver therapy appears to exert less influence on the course of the anaemia than in pernicious anaemia. Reticulocyte response is usually poor and delayed.

(viii) In the case with progressive anaemia, one transfusion usually has a dramatic and permanent effect, but rare cases need massive transfusion before a response is obtained.

(ix) Iron therapy often produces dyspepsia and diarrhoea and is of doubtful value.

Unfortunately, sternal punctures have had to be omitted.

SUMMARY AND DISCUSSION OF THE PICTURE OF RELAPSE AND REMISSION

Hitherto, sprue has presented such a diversity of symptoms that its natural history as a disease process has been practically incomprehensible.

Observation of symptoms and signs in these cases has revealed a sequence forming an intelligible pattern in the large majority of cases.

Symptoms may be grouped into (a) those of onset and relapse phase and (b) those of remission phase. These alternate symptoms of onset and relapse are :—

(a)	(i) Diarrhoea (ii) Anorexia (iii) Weakness (iv) Vomiting (v) Loss of weight	Onset or relapse phase
(b)	(i) Sore tongue, glossitis, and cheilosis (ii) Distension (iii) Gain of weight (iv) Large appetite (v) No diarrhoea, sometimes constipation (vi) Increase of flatulence (vii) Scaling of the skin	Remission phase

In the stage of transition from relapse to remission, various combinations of these symptoms are found.

The majority of cases described here were acute sprue mild, with apparent recovery after only a few mild relapse phases.

Any of these may, however, develop as illustrated into the severe form of the disease with gross loss of weight and dehydration. It is in this stage that sulphaguanidine, parenteral liver therapy and transfusion are life saving, and often take the patient straight through remission to apparent recovery.

Classical sprue syndrome probably develops through repeated cycles of relapse and remission, with slow steady loss of weight. These cycles cover a period of years.

Malnutrition may thus occur in acute form in the early stages, and again in a chronic form later. It is unlikely that the malnutrition of classical sprue will respond so well to therapy as structural atrophic changes have probably developed.

These two phases are reflected in barium meal examinations, fractional test meals, blood picture, and may be summarised as follows :—

	Relapse phase	Remission phase
Barium meal	*Bolus formation* Absent mucosal pattern Increased motility (marker time)	*No bolus formation* Presence of mucosal pattern Normal motility (marker time)
Fractional test meal	Hypochlorhydria more common	Normal or hyperchlorhydria
Blood picture	Anaemia slight, normocytic (macrocytic in severe cases)	Macrocytic anaemia

INTESTINAL ABSORPTION IN RELATION TO RELAPSE AND REMISSION PHASES

Biochemical investigation carried out on the series B. 80 was not designed to compare the condition during these two phases. Cases

selected for such investigation were those who had been severely ill or were failing to respond to diet therapy. Cases in severe relapse were medical emergencies and little opportunity existed for investigating this stage. In few instances, however, some data was collected, particularly if a patient relapsed whilst in No. 3 IBGH. Cases in marked remission consisted mostly of those who responded well to diet therapy and who were not considered suitable for biochemical investigation.

Information on the biochemical aspect of change from relapse to remission is thus scanty. The following changes are briefly mentioned. They are described and discussed in greater detail later in this chapter.

Relapse Phase : In the presence of diarrhoea of whatever aetiology there is diminution of absorption of most if not all food substances. If the diarrhoea in a case of sprue be considered part of the disease, then it may be said that in relapse phase there is marked diminution of fat absorption, as calculated by fat balance tests and chylomicron curves; of sugar absorption as judged by blood sugar curves ; of protein absorption in one case in relapse on which a nitrogen balance could be done and as judged by low plasma proteins in several. In the case with the negative nitrogen balance this was due to a rise in faecal nitrogen which might have resulted from primary failure in absorption or from excess of intestinal secretions. Electrolytes were also deficiently absorbed as judged by excess of faecal sodium with low blood levels of this element in a case in severe relapse. Serum iron too in one case was low at the end of relapse phase.

Finally plasma volumes were low in relapse, reflecting the dehydration of this phase.

Thus, in relapse phase there is some evidence that a general absorption defect affecting protein, fat, carbohydrate, water and salts is present. To what degree such deficiencies are to be considered specific to sprue could only be assessed by a careful comparison with the changes in other diseases in which diarrhoea is a prominent symptom, for example, proved dysenteries, tuberculous enteritis and malnutrition in temperate climates. Whatever the primary absorption defect in sprue may be, it is rapidly overlaid by secondary deficiencies in the diarrhoeic phases of the disease.

Remission Phase : This phase can be considered in two stages : (a) on diet alone and (b) resulting from parenteral liver therapy.

(a) Those cases which had gone into satisfactory remission on diet alone had not had complete biochemical investigations. In most of these it can only be said that over a period of two to three months, weight steadily increased indicating at least absorption from the bowel adequate for such an occurrence. Fat absorption, as reflected in a drop in steatorrhoea to below 30 per cent., improved in 37 out of 52 cases. Chylomicron curves on such patients are normal. It is probable that significant improvement in fat absorption occurs late in remission.

Blood sugar curves had not often been done in these cases, nor had other estimates of absorption, so that it is not possible to analyse further changes in patients responding satisfactorily on diet therapy.

(b) Acute cases in severe dehydration and those failing to develop satisfactory remission on diet therapy alone, respond with few exceptions to the addition of parenteral liver therapy. In such cases there are further biochemical evidences of the induced remission.

Fat Absorption : This is improved. Such improvement may be largely if not entirely accounted for by the cessation of diarrhoea, or there may be some specification resulting in improvement of absorption. In any case, absorption improves but does not become normal, and further, improvement during remission beyond about 70 to 80 per cent. of ingested fat is slow.

The chylomicron curve in most cases changes sharply from flat to normal after parenteral liver therapy, i.e., in early remission and not parallel to the improvement of fat absorption.

Sugar Absorption : In some cases, the blood sugar curve improves markedly soon after parenteral liver is given, but this is by no means constant.

Protein Absorption : In all cases where nitrogen balances were done in this stage they showed nitrogen retention, though faecal nitrogen was usually slightly raised. Absorption and utilisation are thus adequate at this stage for weight gain.

Plasma proteins usually show rise early in remission after the dehydration has been overcome.

Electrolytes : Sodium was still in excess in the faeces one month after liver induced remission had commenced in one case, but blood sodium levels had been restored to normal.

Water Absorption : The first action of liver noticed clinically is the production of formed stools as opposed to the watery or creamy diarrhoea of severe relapse. This suggests marked increase of water absorption and coincides with gain in weight of the patient.

CONCLUSIONS

The clinical features of the early symptoms of sprue as seen in British soldiers from 1943-45, have been found to present themselves in two groups. These have been termed symptoms of onset or relapse, and symptoms of remission. The alternation of these produces the very variable symptomatology of sprue. Where transition from relapse to remission phase is delayed, a mixed picture presents itself. Such patients do not gain weight.

During relapse dehydration is responsible for some of the clinical features found. Barium meal shows gross obliteration and loss of intestinal mucosal pattern, and absorption of protein, fat, carbohydrate, water and salts is grossly affected. During remission, many of these defects remain for at least one to two months, in spite of rapid gain of weight and marked clinical improvement.

In remission, blood changes consisting of macrocytic anaemia persist until weight returns to normal. Hypotension persists, and may

even develop in this phase. Absorption of fats and sugars improves only late after one to two months in spite of liver therapy. Early improvement occurs, however, in protein absorption and utilisation, and in water absorption.

Signs which may be interpreted as those of avitaminoses A and B groups occur at transition from relapse or in early remission.

It will be apparent that remission is in no sense synonymous to cure, for the tendency to relapse appears to remain after clinical restoration to health.

BIOCHEMICAL ASPECTS OF SPRUE

The biochemical approach to the problem of sprue has in general based itself on blood estimations, and on estimations of the percentage of fat in the fresh or dried stool. For example, Fairley (1936) carried out estimations of the serum bilirubin, calcium, phosphate and cholesterol, finding low values for the serum cholesterol in most cases. The increase of fat in the stools is often obvious to naked eye or on microscopic examination, and an increased percentage of fat in random samples of stools was frequently reported. Later, Barker and Rhoads (1937), De Langen (1940), and Adlersberg and Sobotka (1943) used blood-fat curves as an index of fat absorption in sprue.

In this study, three methods of assessing fat absorption *viz.*, faecal analysis on a controlled diet, the chylomicron count, and blood fat curves after a standard meal have been used.

(i) *Faecal Fats :* As Pratt (1934) and others have pointed out, in order to study cases of fatty diarrhoea adequately it is necessary to maintain the percentage absorption of fat. As will be seen from the subsequent detailed discussion, this method is well adapted for studying long-term changes in fat absorption but the need to use collection periods of adequate length makes it unsuitable for studying rapid changes in fat absorption.

(ii) *Chylomicron Count :* This has been extensively used by Frazer (1940) in his important studies on normal fat absorption. It has the important practical advantages of using only finger-prick samples of blood, and of being rapid to carry out. On the other hand it is difficult to place much quantitative stress on a simple count of particles of varying size, and the chylomicron count does not show any close correspondence with simultaneous fat estimations in the serum.

(iii) *Blood Fat Curves :* These have accordingly been used as the standard method for short-term experiments with the addition to the standard meal of substances which might be expected to influence fat absorption. Blood fat curves, do not measure total absorption in the same way as stool fat analysis on a known diet ; but they do give information on the rate of absorption, with limitations to be discussed later. The information which has been gained by these methods on fat absorption is dealt with here. The absorption of non-fatty substances has also been studied for comparison with fat absorption. Some more general

biochemical observations are also included. The relevance of the information gained in relation to current theories of the mechanism of sprue is then discussed.

THE MEASUREMENT OF TOTAL FAT ABSORPTION

Since an impairment in the absorption of fat is the most constant and characteristic feature in the biochemical picture of the sprue syndrome, any investigation into the biochemistry of sprue should be firmly based on adequate methods of measuring fat absorption. It is obvious enough that the routine diagnostic procedure of estimating the fat percentage in a dried random sample of stool is quite inadequate for any quantitative survey of fat absorption in sprue, for it takes no account of the amount of fat in the diet, nor of the variation in faecal fat content from day to day, or even from stool to stool. Even if the fat content of the diet is controlled for some days beforehand, there is still no certainty that a single specimen of stool would represent a fair sample of fat excretion. It is, therefore, necessary both to control the diet, and to collect the total faeces over three or four day periods, and analyse a sample of the well mixed and weighed stool, expressing the result not as a percentage figure, but as grammes of fat excreted per day. This procedure has the advantage that variations in the amount of water left in the stool after routine 'drying' do not affect the final result, for any lowering of the fat percentage due to incomplete drying is compensated by an increase in the ratio of dry to wet faecal weight, which is included in the calculation.

The patients undergoing metabolic investigation were put on a weighed diet and food residues were also weighed. The fat content of the diet was calculated from food tables (McCance and Widdowson, 1940), and the fat content of the main sources of fat in the diet was checked by periodic analysis to ensure that they conformed to the values given in the tables for English foodstuffs. The capricious appetite of sprue patients caused considerable deviations from the planned fat content in some cases ; the appropriate corrections based on the amount of food left over have been made in each case in calculating the percentage of fat absorption.

The total stools for three or four day periods were collected in large tin vessels and preserved with formalin. Carmine and iron markers were used to aid in the demarcation of the periods. The stools were weighed, and thoroughly mixed with a large ladle, and samples of 20 to 50 g. depending on the wateriness of the stool, were transferred to weighed Petri dishes, and air dried on a warm surface under a fan. The wet and dry weight of the sample was determined. One gramme samples of the dried stool were treated with 30 per cent. hydrochloric acid for ten minutes in a boiling water-bath, and extracted thrice with ether in a Stokes tube. The ether extract was dried and weighed to give the fat content of 1 g. of dried stool ; this was multiplied by the total calculated weight of dry stool to give the fat excretion in three or four days. The fat was redissolved and the split fat determined by titration

with N/10 alcoholic soda. The percentage fat absorption was calculated from the fat output and the fat content of the diet. This calculation involves the assumption that true excretion of non-dietary fat is negligible in comparison with unabsorbed fat derived from the diet ; evidence in favour of this assumption is given later.

VARIATION IN FAT OUTPUT

When stool collection over consecutive three or four day periods was begun, it was soon observed that in the same patient on the same diet there was a considerable fluctuation in the fat output from one period to the next. Duplicate estimations showed that the error of actual estimation of the fat content of the dried stool was less than 5 per cent., whereas the total stool fat in successive periods might vary by 50 per cent. or more of the mean value. The variation in the fat content was closely connected with the total weight of dry stool, and it seemed likely that the high results in some periods and the low results in others were caused by a failure of the four day faecal period to correspond accurately to a four day dietary period. When 'markers' such as carmine and iron were given in the diet at four day intervals, this suspicion was partly confirmed by the different time intervals which elapsed between the giving of the marker and its passage in the stool ; but although the use of markers did stabilise to some extent the apparent fat output, considerable variations from one period to the next remained. (Table V).

TABLE V

Variability of stool fats with and without markers—sprue cases.

Stool total dry weight g./4 days	Stool total fat g./4 days	Mean of four period g./4 days	Standard deviation	Coefficient of variation
Patient I.				
Without markers—				
264	96			
203	71	59	+22·6	38·4
83	32			
118	37			
With markers—				
217	75			
220	53	50·5	+13·9	27·5
107	33			
160	41			
Patient II.				
Without markers—				
132	25			
214	96	48·75	+26·4	54
111	53			
66	21			
With markers—				
83	34			
264	111	78	+24·6	31·6
156	75			
286	92			

illustrates the effect of markers on the variability of apparent fat output; it will be seen that even with markers the output of fat is far from constant in successive periods. It must be emphasised that even with markers the four-day period is still not a 'true' four-day period; for a marker given with one meal appears in several stools, and also one cannot assume that all constituents of the diet pass through the bowel at the same speed as the marker. This intrinsic large error in the stool collections makes it necessary to draw conclusions as to changes in faecal fat only from long periods of twelve days or more.

FAT ABSORPTION IN UNTREATED SPRUE

Table VI shows the percentage fat absorption in 17 patients with early sprue, who were receiving no treatment other than rest and a measured diet containing either 69 g. or 96 g. of fat per day.

TABLE VI

Percentage fat absorption in untreated cases of early sprue without diarrhoea[1].

Patient	Percentage of ingested fat absorbed	
1	72	
2	51	
3	67	
6	77	
7	78	
8	80	Mean 76 per cent.
9	71	
10	73	Range 51 to 89 per cent.
12	82	
14	77	
15	79	
16	83	
17	82	
20	70	
21	85	
23	89	
24	77	

On a mixed diet with a fat content of 50 g. to 100 g. of fat per day, normal people absorb 90 per cent. or more of the ingested fat. None of the patients with untreated sprue absorbed more than 90 per cent. or less than 50 per cent. On an average 3/4 of the ingested fat was absorbed. Six patients had more than one twelve-day period before treatment was begun, and their figures, given in Table VII, show the degree of variation which can be expected in the results of this method in patients not showing spontaneous improvement. Two patients, whose

[1] Percentage of fat absorption was calculated as follows: $\frac{\text{Dietary fat} - \text{Excreted fat} \times 100}{\text{Dietary fat}}$.

later curve showed that they were improving spontaneously without any specific treatment, have been excluded from this table.

TABLE VII

Percentage fat absorption in consecutive twelve-day periods on patients not receiving specific treatment.

Patient	Percentage fat absorption		
	Period 1	Period 2	Period 3
6	78	78	75
12	82	88	81
14	77	74	...
15	79	75	...
17	82	83	...
24	77	80	...

The variation between consecutive twelve-day periods is not large, and it is possible with this method to get a satisfactory base-line value for fat absorption before starting treatment. The method cannot, however, be well applied to patients with watery diarrhoea, in whom the errors in collecting and analysing stools are larger than in patients with formed stools. The effect of various forms of treatment on fat absorption is considered later in this chapter.

DIARRHOEA AND FAT ABSORPTION

It is well recognised that simple diarrhoea may cause deficient splitting and deficient absorption of fats. (Harrison, 1937). Data bearing on this matter in sprue patients admitted to No. 3 IBGH are meagre, because there the general policy was to wait until diarrhoea had cleared up with rest in bed, and in some cases with sulphaguanidine, before starting a fat balance experiment. Observations on five patients with diarrhoea, shown in Table VIII are, therefore, to be regarded as incidental rather than as a planned experiment.

TABLE VIII

Percentage fat absorption with and without diarrhoea.

Patient	Without diarrhoea	With diarrhoea
3	67	64
4	80	75
5	73	55
11	61	30
18	73	80

Of the five patients, four showed improvement in fat absorption when the diarrhoea was controlled ; the fifth patient had fairly good absorption even in the phase of diarrhoea. The improvement in fat absorption when the diarrhoea was brought under control with liver treatment is specially striking in patients 5 and 11, who showed the lowest fat absorption before treatment.

FAT ABSORPTION IN DIETS OF DIFFERENT FAT CONTENT

Five patients who had had a twelve-day period on a diet containing 69 g. of fat per day were changed to a diet with 96 g. fat per day.

TABLE IX

Percentage fat absorption on diets of different fat content.

Patient	Percentage fat absorption	
	69 g. fat per day	96 g. fat per day
1	82	83
2	80	74
3	83	88
4	85	87
5	51	44

In four of them this increase in fat content of the diet was followed by no greater variation in the percentage of fat absorption than was observed in the same patients on a constant diet (Table VII). The fifth patient, who showed a fall of seven per cent. in his fat absorption, had an initial defect in fat absorption much greater than any of the other patients. The general conclusion to be drawn from this experiment, is that a moderate increase in fat intake does not impair the absorption of fat in sprue, unless this is already unusually low. It must be emphasised that the increase in fat intake was purposely limited, and this result has no bearing on the general advisability of restricting the fat intake in cases of sprue.

On a diet containing minimal amounts of fat (6 g./day), both normal subjects and patients with sprue excrete very small amounts of fat. The fat which appears in the stools must be mostly secreted fat since it can be assumed that in normal people not more than 1 g./day of the 6 g. of ingested fat will appear in the stools. The figures given in Table X show that on the 'fat-free' diet the steatorrhoea in the sprue patients disappears. Similar findings in this respect are quoted

by Wintrobe (1942). These results make it unlikely that a pathological secretion of fat by the intestine plays any significant part in the causation of steatorrhoea in sprue.

TABLE X

Fat excretion (marked three-day periods) on a low fat diet.

Subject	Period 1	Period 2	Period 3	Period 4
Sprue A	41	5·6	6·5	32
Sprue B	75	23	7·3	63
Normal A	15	18	6·1	16
Normal B	21	26	4·2	12

All the figures represent the total fat excretion in g./3-days. In two periods, 1 and 4, the diet contained 96 g. fat/day and in periods 2 and 3, 6 g. fat/day. The high values in period 2 for three of the subjects are presumably due to 'carry over' of stool from period 1, in spite of marking.

THE NON-FAT DRY RESIDUE

When the total fat in a stool is subtracted from the total dry weight, the residue is termed non-fat dry residue (NFDR). This is very largely composed of bacteria, but it also contains unabsorbed food residues from dietary constituents other than fat. In a given patient on a constant diet without treatment, the NFDR does not change much, when measured for adequate periods of time. If an unabsorbable food such as a barium meal is given, there is an increase in the NFDR. Table XI shows the total fat and NFDR in two twelve-day periods in ten patients, the first twelve-day period being before treatment, and the second after full treatment which has diminished the steatorrhoea.

TABLE XI

Fat output and NFDR in twelve-day periods before and after treatment.

Patient	Fat (g./12-day)		NFDR (g./12-day)	
	Before	After	Before	After
2	311	164	303	254
3	376	222	505	487
6	237	105	240	288
7	283	105	400	377
8	235	175	412	397
9	328	179	289	296
14	499	191	418	354
15	286	209	292	340
17	235	139	343	317
24	269	216	612	410

Seven patients had a smaller NFDR in the second period, the amount of the decrease bearing no quantitative relation to the decrease in steatorrhoea. One patient had no definite change in the NFDR, and two had a rise in the NFDR although steatorrhoea had diminished in both cases. The higher values for NFDR in many patients at a period when steatorrhoea is severe may mean that more bacteria are being passed in the stools, or that substances other than fat are being improperly absorbed. From the point of view of practical diagnosis the general trend in NFDR makes estimation of the percentage fat content of dried stool a less sensitive index of improvement in the steatorrhoea than estimation of total fat excretion.

WATER CONTENT OF STOOLS

With gross variations in steatorrhoea such as occur with treatment in sprue, a fair measure of the water content of the stool cannot be obtained simply from the ratio of dry to wet stool weight, for the fatty part of the stool is not wetted. The 'percentage water content' used is, therefore, derived from (wet weight of stool-fat) and (dry weight of stool-fat). Table XII shows the average figures derived from 66 stools taken at different times from 11 patients with sprue and grouped according to their percentage fat content.

TABLE XII

Relationship between fat content (percentage of dry weight), and water content of stools.

Fat (percentage of dry weight)	Mean water content (percentage of non-fat wet weight)	Standard deviation of mean
Less than 30	76·9	±6·35
30 to 40	79·95	±4·39
Over 40	81·5	±6·44

The difference between the means are significant (P less than 0·02).

It will be seen that stools of higher fat content have also got a higher percentage of water, although the series was limited to formed stools. As pointed out in the previous paragraph, many patients with sprue have a higher NFDR when steatorrhoea is gross so that the percentage figures just given minimise rather than exaggerate the total amount of water lost in the more steatorrhoeic stools.

GENERAL CHARACTERISTICS OF THE FATS IN THE SPRUE STOOL

Considerable attention has been paid in the past to the degree of 'splitting' of the fat in the sprue stool. It has been found that in general the ratio of split to unsplit fat exceeds the normal ratio of three or four

to one, although occasional stools have been found to contain a larger proportion of neutral fat. The fact that the split fat in the sprue stool generally forms a higher proportion of the total fat than in normal stools has sometimes been taken to imply a defect in the absorption of split as opposed to unsplit fat; but this neglects the possibility of lipase action in the colon, or in the interval between passage of the stool and analysis.

TABLE XIII

Splitting effect of normal and sprue stools.

Stool	Percentage of fat in stools		Weight of wet stool in experiment g.	Weight of margarine added g.	Days in incubator	Percentage of margarine split.
	Total	Split				
Sprue	44·1	42·8	91	36	3	88·8
Sprue	23·2	20·5	171	40·2	2	97·3
Sprue	41·0	34·8	17·58	2·36	2	90·4
Sprue (sulphathiazole and penicillin) ...	41·6	33·9	20·29	3·40	2	89·4
Sprue (sulphathiazole+penicillin+copper sulphate) ...	41·6	33·9	18·44	2·82	2	54·6
Normal	18·4	12·2	52·5	23·5	2	40
Normal	22·4	16·6	12·32	3·40	2	81

It was found that incubation of margarine with both normal and sprue stools leads to the splitting of the greater part of the added margarine, if any thing, sprue stools are more active in this way than normal stools, probably because of the emulsifying action of the large amount of soap in the sprue stool. The addition of sulphathiazole (one per cent.) and penicillin (20 to 30 units/cc. of stool) did not inhibit the splitting of margarine, so that aerobic bacterial action is not responsible for the lipolysis. On the other hand, saturated copper sulphate solution added in the proportion of 5 per cent. partly inhibited the splitting. This demonstration of lipolytic activity in the stools prevents any deductions being drawn from the split : unsplit ratio in the material, which consisted of three or four day specimens. Even in fresh stools it is not possible to say how much of the split fat found may not have been produced during incubation in the colon. The generally observed increase in split fat in sprue stools is best explained on the basis that unsaponifiable fat is the same in normals and sprue patients but the amount of saponifiable fat is much increased in sprue. It was found that a high proportion of the split fat in the sprue stools is present in the form of soaps, in spite of the fact that most of the stools were acid in reaction. Table XIV shows the percentage of the split fat occurring as soaps grouped in relation to the total percentage of split fat in 46 stools from ten sprue patients. The percentage of split fat present

as soaps was over 60 per cent. in 87 per cent. of the stools examined. It can be seen from the table that stools have a high proportion of fat present in the form of soap, irrespective of whether they contain large amounts of split fat or not ; the fixation of electrolytes in the form of soaps will in general increase as the total fat content of the stool increases. A considerable part of the soap in the sprue stool is insoluble in water and in ether, and was found by analysis to contain calcium. On the other hand stools with a higher soap content have been found to be higher in pH than stools of low soap content, suggesting that some of the soap is ionised, and therefore, in solution ; also an abnormally high amount of sodium was found in one formed stool, as an incidental finding in the observations on electrolytes reported later on.

TABLE XIV

Number of stools with grouped percentage soap content relative to percentage of split fat in dry stool.

Split fat (Total dry weight percentage)	Soap fat (Split fat percentage)		
	Under 60	60–80	80–100
20–40	5	11	10
40–60	1	14	5

The average molecular weight of the saponifiable fatty acids in eight normal and forty sprue stools was determined by calculation from the weight of the saponifiable fraction, and the titration value of N/10 solution of sodium hydroxide needed for neutralisation. The average molecular weight was 273 in the normal stools and 271 in the sprue stools. The difference was not considered to be significant.

OTHER PROPERTIES OF THE SPRUE STOOL

The pallor of the typical sprue stool has usually been attributed to reduction of bile pigment and to the colourless stercobilinogen. It was confirmed that the total amount of bile pigment in the sprue stool is not abnormally low. Besides the presence of stercobilinogen, the pallor of the sprue stool is also due to its increased bulk, which dilutes the pigment in it. It was found that there is some relationship between the increase in pallor and increase in fat content; the correlation, however, is not close.

Approximate readings of pH were made on 91 sprue stools, using bromothymol blue and bromocresolpurple indicator papers with BDH capillator standards. The observed range of pH was from 5·8 to 7·4, the average being 6·7 ; these values are less acid than those reported by Thaysen (1932). Table XV shows the pH values grouped in relation to the percentage of split fat in the dry stool. The figures represent

the number of stools in each category. The pH is significantly higher in the more fatty stools. This can best be explained by the higher content of soaps in the more fatty stools.

TABLE XV

Stool pH grouped according to percentage of split fat in the dry stool.

Split fat (Dry stool weight percentage)	pH			
	Below 6·2	Above 6·2	Above 6·6	Above 7·0
Below 30	11	11	12	6
Above 30	5	6	17	23

The pH is higher in the more fatty stools, $X^2 = 13 \cdot 36$, P(0·01).

Together with the observations on soap content, these readings of pH suggest that the well known character of very fatty stools is due not to excessive acidity, but to a high content of soluble soaps. The practice of giving calcium salts to diminish diarrhoea has, therefore, some theoretical justification in that it would increase the proportion of insoluble soaps at the expense of the irritant soluble soaps.

OBSERVATIONS ON THE CHYLOMICRON COUNT CHANGES IN SPRUE

The blood contains minute particles of fat which are visible by dark ground illumination with high power magnification. These particles were known as haemoconia; the name chylomicron is now generally used. Changes in the number of particles during the absorption of fat have been studied in normal people by many observers, particularly by Frazer and Stewart (1937).

The speed with which chylomicron curves, after a fatty meal, can be done, and the relatively slight inconvenience to the patient, suggested that the method might be usefully employed in an investigation of fat absorption in sprue. The results of 83 chylomicron curves in 28 patients with sprue, together with curves in normal subjects, using the same technique are given here. Other data obtained in the same investigation permit a comparison of the chylomicron count in individual cases with the percentage fat absorption on a controlled diet with blood fat curves, and with glucose tolerance curves. In those cases where several counts have been done at different stages of the disease it has been possible to relate the count to the patient's clinical condition.

The technique used was that of Frazer and Stewart (1937). The fatty meal consisted of 200 cc. of homogenised evaporated milk, containing 18 g. of fat. It was given after a 12-hour fast. Counts were usually made on serum from specimens of capillary blood, but whenever venous blood had to be taken for other estimations, this was used

to provide serum for the count. Except for high counts, counts done on venous and capillary blood taken at the same time do not differ.

Counts are made on a small drop of serum spread out by pressure between slide and cover-slip. They are estimated in terms of the number of particles per standard field. Specimens were taken immediately before and at half hourly intervals after the meal, for four or five hours. The first and usually the second half hourly specimens were omitted.

Capillary tubes about 5 cm. long and of 1 mm. internal diameter were used. These tubes allow satisfactory clot retraction when new, but the clot adheres to the wall if they are used after repeated cleaning. Microscope slides of a standard thickness (1 mm. to 1·1 mm.) must be used to ensure standard conditions of illumination of the dark ground field. They are cleaned with dichromate solution followed by spirit.

Blood from the finger obtained by a needle stab, is allowed to flow in a continuous column into the capillary tube until it is almost full. The tube is then stuck into plasticine, upright, with the unfilled end uppermost. A slab of plasticine on a microscope slide takes eight or ten specimens for a serial count. After the blood has clotted in the tube, the upper end of the clot is gently freed from the tube wall with a stilette. The clot then retracts leaving a clear column of serum.

It is most convenient to start the count when all the specimens have been collected. A small drop of serum is transferred to a slide by means of finely drawn out capillary. A cover-slip is placed on the drop and gently pressed down with a piece of gauze, and any excess of serum is wiped away. The depth of such a film of fluid, which causes the two glass surfaces to adhere is determined mainly by the physical properties of the fluid and is reasonably constant.

In examining the preparation by dark ground illumination particular care must be taken to secure optimal illumination, since with inadequate light, excessively thick slides, or a condenser badly centred or focussed, false low counts will be obtained. With satisfactory lighting the few red cells present show up as a uniformly bright ring of light. The chylomicrons are refractile about 1μ in diameter and show rapid Brownian movement. They may be confused with granules from leucocytes, but such granules, unlike the chylomicrons, have a dark centre. Particles indistinguishable, except by their immobility, from chylomicrons may be seen fixed to the slide or cover-slip but they are relatively few when clean glassware is used. Since many may be seen in preparations known to contain few chylomicrons they are ignored in making the count.

The standard field on which the counts were based was that obtained with a 1/12 inch objective and X15 eye piece. Up to 50 chylomicrons can be counted in such a field, but when the counts rise to higher numbers, a smaller field is used. This was obtained by inserting a diaphragm in the eye pieces, giving an area one-fifth of the large field. Such a diaphragm may easily be made from paper cut into a disc from which a section with an angle of 72 degrees has been cut out.

The chylomicrons are counted to the nearest five and at least five large or ten small fields should be counted and the average taken

because the particles are not quite evenly distributed in the preparation. The count is made on only one depth of focus. For a given observer the variation found in doing several counts on different preparations made from the same specimens of serum is about +15 per cent. Since the smallest particles are invisible and only those are counted which are definitely visible, there is a large subjective element in estimating the count. The great variation in particle diameter, implying a variation in particle volume of several hundred fold, makes these sources of error comparatively negligible when attempting to use the count as an index of fat absorption, since no allowance is made for variation in particle size.

NORMAL VALUES

Eighteen curves done on eleven normal men with the standard meal are shown in Table XVI. The fasting counts vary between

Table XVI

Normal chylomicron curves.

Subject No.	Fasting count	Hours								
		1	1½	2	2½	3	3½	4	4½	5
1	26	14	64	111	180	116	111	120	...	...
2	7	10	55	138	170	40	55	52	...	...
2	20	18	57	77	106	45	39	37	...	...
3	74	34	94	136	135	124	66	35	...	...
3	40	83	132	140	162	107	45	28	48	21
4	8	...	58	94	119	122	61	60	...	...
5	20	...	49	95	142	118	131	86	...	...
6	9	...	34	53	80	105	70	47	43	23
7	2	6	34	54	58	137	109	42	57	39
8	6	15	46	73	125	68	123	83	76	37
8	16	...	89	105	143	137	166	75	54	35
8	2	...	...	128	97	90	44	33	...	10
9	4	90	105	270	200	140	70	160	40	15
10	15	...	125	185	140	105	85	20	...	...
11	1	...	15	20	20	100	30	40	...	...
3	5	...	...	150	230	140	...	30	...	...
8	10	...	30	110	130	70	60	5	5	...
7	5	...	80	70	120	110	80	35	20	15

1 and 74. Only 3 are over 20. The time of the peak value of the count after the meal is fairly constant and in all curves lies between 2 and $3\frac{1}{2}$ hours and is at $2\frac{1}{2}$ hours in 10 of the curves. The peak value is very variable averaging 150 (SD+43·5, range 100-270). The height of the peak may vary by more than 50 per cent. from time to time in the same person.

These results are comparable to those obtained by Frazer who found that the curve reached maximum rise in $2\frac{1}{2}$ hours. He found somewhat higher counts and this may be attributed to the use of a different meal.

RELATION BETWEEN CHYLOMICRON RISE AND THE AMOUNT OF FAT ABSORBED

Changes in the curve in the same person caused by varying the test dose of fat are shown in Table XVII.

Table XVII

Curves on one person after varying quantities of fat.

Fat	Fasting count	Hours									
		1	$1\frac{1}{2}$	2	$2\frac{1}{2}$	3	$3\frac{1}{2}$	4	$4\frac{1}{2}$	5	Average at peak
9 g.	13	12	65	85	30	80	45	7	8	...	60
18 g.	74	34	94	136	135	124	66	35	...	...	132
18 g.	40	83	132	140	162	107	45	28	48	21	136
18 g.	5	...	...	150	230	140	...	30	...	...	173
36 g.	23	135	190	270	410	380	325	190	215	...	372
36 g.	5	8	74	165	190	330	310	125	...	...	277

Reducing the standard dose of fat by half produced a lower peak and doubling the dose, a markedly higher peak. This relationship provided evidence that the increase in the number of chylomicrons during fat absorption is due to absorbed fat, and the question arises whether the rise depends on the total amount of fat absorbed, or on the rate of absorption or on the form in which the fat appears in blood stream.

It was found that when a soluble calcium is given with the standard meal a low chylomicron curve results.

TABLE XVIII

Effect of calcium salt on chylomicron curves—simple milk meal.

Name of subject	Fasting count	Hours 1	1½	2	2½	3	3½	4	4½	5	Remarks
PF	74	34	94	136	135	124	66	35	...	...	*
DB	20	18	57	77	106	45	39	37	...	...	†
PM	10	...	30	110	130	70	60	5	5	...	
PR	6	...	80	70	120	110	80	35	20	15	
Meal with calcium salt.											
PF	13	10	20	28	80	80	42	4	...	...	‡
DB	9	6	9	28	47	80	30	25	...	...	‡
PM	70	...	7	20	43	25	25	15	10	10	§
PR	5	...	15	15	...	50	20	15	10	...	§

*Lowest of 3 curves on this subject. ‡With 10 gms. calcium glycerophosphate.
†Lower of 2 curves on this subject. §With 7½ gms. calcium lactate.

To determine whether the low chylomicron count corresponded to a diminution in the amount of fat absorbed a balance experiment on two normal subjects (PM and PR) was carried out. The diet contained 95 g. of fat per day and 30 g. of calcium lactate were given per day in divided doses, with each meal, for six days. A carmine stool marker was given at the beginning and at the end of the six day period, and the total fat in the stools for that period and for periods before and after the experiment was estimated. The results of the experiment are shown in Table XIX.

TABLE XIX

Effect of calcium salts on fat absorption.

Normal subject	Average daily total fat content of stool: During six days before giving calcium lactate	During six days of calcium lactate administration	During eight days after giving calcium lactate
PM ...	9·3 g.	11·8 g.	11·6 g.
PR ...	4·3 g.	8·0 g.	6·4 g.

It will be seen that though $7\frac{1}{2}$ g. of calcium given with the standard meal produced in these subjects low curves, this dose of calcium given four times a day with a diet containing 95 g. of fat per day did not produce steatorrhoea. The low chylomicron counts observed with calcium lactate reflect either a change in the rate of fat absorption or a change in the form in which the fat appears in the blood stream, but do not indicate a gross diminution in the total amount of fat absorbed.

Further evidence on the relation between chylomicron count and the total amount of fat absorbed is derived from 38 curves on sprue patients whose fat intake and output was being measured.

TABLE XX

Relation between height of chylomicron count and percentage of ingested fat absorbed.

Chylomicron peak count	Percentage of dietary fat absorbed				
	Below 60	60–70	70–80	Above 80	Total
Below 100 ...	3	5	5	4	17
Above 100 ...	3	4	6	8	21
Total ...	6	9	11	12	38

The chylomicron curves have been grouped according to the peak value, above and below 100. Of the 17 curves with a peak below 100, 13 had a peak below 80. The table shows that while an abnormally low chylomicron count is common, when fat absorption is poor, the incidence of low counts is not quantitatively related to the severity of the fat absorption defect. A normal count is common when 30 per cent. of the ingested fat is not being absorbed, as in an average case of sprue. This high proportion of normal curves with definite steatorrhoea is not surprising when it is considered that the greater proportion of ingested fat is being absorbed. On three occasions, however, normal curves were found when only 50 to 60 per cent. of the ingested fat was being absorbed. Such cases suggest that chylomicrons may represent only a fraction of the blood fat, the level of which may rise during fat absorption though total fat absorption be poor.

A study of 37 chylomicron counts done concurrently with serum fat curves in which the total fatty acids, total cholesterol and lipid-phosphorus were estimated, might be expected to show whether chylomicrons are derived from any of the recognised fractions of the blood lipids. The serum lipid estimations were done as part of a study of intestinal absorption in sprue and are to be reported in full later.

FASTING VALUES

The fasting values of the chylomicron curves in the fat curve series fell into two groups : 31 were under 30 and 6 were over 40.

No significant difference was found in the fasting values for total fatty acid, phospholipids or total cholesterol in these two groups.

CURVES

In relating the chylomicron counts to the change in the serum lipid fractions during fat absorption, the fasting value of each lipid fraction has been deducted from the subsequent values of the curve, so as to minimise the effect of the variation due to the widely differing fasting values. No such correction has been applied to the chylomicron counts, since in most cases with a fasting count, the count drops before rising to the usual peak. Moreover, for the peak values the correction to be applied would in most cases be less than the error of the count.

Table XXI shows a significant association between the increment in total fatty acids and the height of the peak of the chylomicron count. The total fatty acids consist of neutral phospholipid and cholesterol-bound fractions.

TABLE XXI

Association between chylomicron peak and total fatty acid increment.

Chylomicron peak count	Total fat mg. percentage in blood	
	Below 40	Above 40
Below 100 ...	12	3
Above 100 ...	7	15
Total	19	18

TABLE XXII

Association between chylomicron peak and phospholipid increment.

Chylomicron peak count	Phospholipid mg.	
	Below ·5	Above ·5
Below 100	8	7
Above 100	9	13
Total	17	20

Table XXII shows no significant association between the chylomicron peak value and the phospholipid rise ; increments in the total blood cholesterol when they occurred were too small to account for except for a fraction of total fatty acid increment. On the other hand the association of the chylomicron peak value with the neutral fat rise was found to be at least as strong as that with the total fatty acid increment. With values derived from 34 curves, 9 normal and the rest from sprue cases, the correlation coefficient for the two associations were found to be ; for the neutral fat increment 0·378, and for the total fat increment 0·331. The standard error of these two coefficients is 0·17, hence only the first is in fact statistically significant. The fat curves and corresponding chylomicron counts from which these correlation co-efficients have been derived are given in another portion of this chapter.

The association between the height of the chylomicron curve and the total and neutral fat increment may be explained by assuming that the chylomicrons are composed of neutral fat.

Though counts to parallel the neutral fat content of the serum were found in several curves, yet when all the results are taken together, it is seen that no close relationship, suggested by Elkes, Frazer and Stewart (1939) was found. Even in individual curves the peak of the neutral fat increment did not correspond with that of the chylomicron count in 21 out of 33 curves and the chylomicron peak occurred approximately as often after as before the neutral fat peak.

Occasionally low chylomicron counts were noticed with high neutral fat increments. This indicates that with absorbed fat as with the fasting serum fats, the chylomicrons may represent only a variable fraction of the neutral fat. The remainder of the neutral fat is invisible, but is known to exist from the results of chemical analysis. If chylomicrons represent absorbed fat, as Frazer's and these results suggest, then it is theoretically possible that a rise in chylomicrons during fat absorption might occur at the same time as a removal of invisible fat to the depots. In such a case the chylomicron count would be expected to rise without any corresponding change in the neutral fat values ; and in point of fact this rise in chylomicrons with little or no change in the neutral fat values has been observed in 3 cases out of 37.

CHYLOMICRON COUNT IN SPRUE

For the purpose of analysis, the curves on sprue patients are grouped according to the height of the peak as follows :—

(i) Peak up to 50.
(ii) Peak 51 to 100.
(iii) Peak over 100.

The distribution of these types of curves is shown in Table XXIII, which gives the number of curves of each type in patients with and

without liver therapy, and with and without diarrhoea at the time of the test. A separate table is given for the first curve done on each patient.

TABLE XXIII

Distribution of three types of chylomicron curves in sprue.

Type of curve	Without liver		With liver		Total
	Without diarrhoea	With diarrhoea	Without diarrhoea	With diarrhoea	
I ...	8	11	0	4	23
II ...	18	2	7	0	27
III ...	23	0	13	1	37
Total ...	49	13	20	5	87

TABLE XXIV

Distribution of first curve on each patient.

Type of curve	Without liver		With liver		Total
	Without diarrhoea	With diarrhoea	Without diarrhoea	With diarrhoea	
I ...	3	3	0	0	6
II ...	9	1	0	0	10
III ...	11	0	1	1	13
Total ...	23	4	1	1	29

Many of the low curves were from patients having diarrhoea, but in the untreated cases of sprue the chylomicron curve is often low even when there is no diarrhoea.

Another common abnormality in the curves in sprue concerns the time of the peak. It is much more variable than in normal curves and frequently late. Curves with a peak value over 50 (groups II and III) were distributed as follows according to the time of the peak :—

Time after giving meal ...	2	2½	3	3½	4	4½	
No. of cases ...	5	20	15	16	6	2	(Total 64)

The average time of the peak was later than three hours in the sprue curves whereas it was two and a half hours in the normal curves.

The occurrence of low chylomicron curves in sprue has been shown not to be simply related to the degree of steatorrhoea. Table XXIII suggests that there is, in cases without diarrhoea, an association between parenteral liver therapy and the occurrence of normal curves.

The changes in the chylomicron count associated with parenteral liver therapy were studied in four cases with an initially low chylomicron count and without diarrhoea. The results are presented in Table XXV.

Table XXV

Effect of liver therapy on the chylomicron curve.

Name.	Liver therapy date. 40 cc. liver extract.	Chylomicron date	Fasting count	1	1½	2	2½	3	3½	4	4½	Percentage fat absorbed
Norris	5 to 8 June 1945	4·6 45	11	13	5	18	47	49	41	50	44	
		9·6·45	3	10	8	17	30	53	66	96	106	
		13·6·45	10	9	18	17	53	51	77	51	82	
		21·6·45	31	5	25	70	68	100	135	81	88	
Cass	1 August 1945	19·7·45	5	...	8	25	89	89	73	56	25	approx. 50
		8·8·45	20	...	6	25	70	130	90	75	50	53
Collier	6 January 1946	3·1·46	3	...	...	...	40	50	50	20	...	57
		24·1·46	2	10	100	200	150	100	50	50	...	82
Burton	16 January 1946	7·1·46	58	...	...	...	46	65	43	44	...	88
		24·1·46	12	10	50	50	40	120	50	20	...	86

In each patient, a normal chylomicron count was found two or three weeks after beginning liver therapy (40 cc. of concentrated liver extract). In three of the patients the proportion of the dietary fat which was being absorbed, as measured in four day periods, was known and the percentage of fat absorbed is shown in the last column of the table. In two of the patients, second and fourth, the change in the chylomicron count was not associated with any improvement in fat absorption. In the third fat absorption had increased.

The curves done on patients not having liver have been grouped according to whether or not the patients were at the time gaining weight. Patients within 10 lbs. of their normal weight and those with diarrhoea are not included.

TABLE XXVI

Association between type of curve and weight gained.

Curve type	Losing Weight	Weight steady	Gaining Weight
I	3	2	1
II	1	11	3
III	1	11	6

A low curve appears to be more common in the patients who are losing weight.

Thirty-five of the chylomicron curves were done within a week of a blood sugar curve. For purposes of comparison the chylomicron curves are grouped into normal and abnormal according to whether the curve reaches a peak of 100 before four hours. The sugar curves are grouped according to whether there is an increment of more or less than 34 mg. per cent. before one and a half hours. Curves on patients with diarrhoea have been excluded.

The association between the groups of curves is shown in Table XXVII.

TABLE XXVII

Association between type of chylomicron curve and glucose curve.

Blood glucose increment percentage	Chylomicron peak curves		Total
	Below 100	Above 100	
Below 34 mg.	11	6	17
Above 34 mg.	5	13	18
Total ...	16	19	35

About two-thirds of the low chylomicron curves were associated with a sugar curve rising less than 34 mg. per cent. and about two-thirds of the normal chylomicron curves were associated with a sugar curve rising more than 34 mg. per cent.

DISCUSSION

The association between the height of the chylomicron curve and the blood glucose curve suggests that the chylomicron curve is a

measure of general absorptive capacity. It has been shown that though the particles consist of fat, the curve is not a measure of total fat absorption so that the chylomicrons represent that quantity of absorbed fat which is dealt differently from the greater part of absorbed fat. The analysis of the curves done concurrently with serum lipid estimations suggests that chylomicrons consist of absorbed neutral fat.

These conclusions are in accordance with Frazer's (1940) partition theory of fat absorption. He claims that fat is absorbed in two ways in the normal subject: (a) as neutral fat which has not undergone any splitting by lipase and is absorbed in particulate form, and (b) as split fat absorbed after phosphorylation. The chylomicrons represent the unsplit fat absorbed without phosphorylation.

Frazer showed that in normal individuals an excess of lipase given with the fat meal produces a low chylomicron count, which he attributes to the fat being absorbed in the split form. The results obtained at No. 3 IBGH with calcium salts may possibly be interpreted as resulting from an activation of lipase (Hawk and Bergeim, 1937). If Frazer's theory is correct, a defect in the absorption of total fat, shown by steatorrhoea, may be present in many cases of sprue in which normal absorption of unsplit fat is indicated by a normal chylomicron curve. Defective absorption of unsplit fat as shown by a low chylomicron curve, may occur particularly in the severe cases. Parenteral liver therapy corrects this abnormality, while total fat absorption is apparently often unaffected. The amount of fat normally absorbed without splitting is probably a small proportion of the whole (Bloor, 1943) and when split fat is not being absorbed the correction of any impairment in the absorption of unsplit fat alone would not be reflected in any detectable improvement in total fat absorption.

The different response to parenteral liver therapy in the absorption of unsplit and split fat suggests that a failure of different mechanisms is responsible for the deficiency in absorption of the two fractions in sprue. It appears that the fundamental deficiency is in the absorption of split fat, which may be due to a failure in phosphorylation (Stannus, 1942). Less specific absorption defects, as of glucose and neutral fat, may be added later in the more severe cases.

SUMMARY

(i) A modified technique for the chylomicron count is described and the results of 18 curves done on normal subjects following the ingestion of a milk meal containing 18 g. of fat are given.

(ii) The curve was shown to vary with the amount of fat given, but in cases of sprue little relation was found between the degree of steatorrhoea and the height of the curve. Low curves were obtained in normal subjects when the meal was given with calcium lactate but this substance did not produce steatorrhoea, suggesting that chylomicrons represent only a part of absorbed fat.

(iii) The relationship between 34 chylomicron curves and serum lipid curves done concurrently were analysed and it was concluded that chylomicrons represent part of the neutral fat in the serum.

(iv) Eighty-seven curves done on patients with sprue were analysed. Low curves were found with diarrhoea and frequently in patients who were not gaining weight. With parenteral liver therapy patients whose curves had been low, gave normal curves after two or three weeks.

(v) The results of the chylomicron curve and blood sugar curve were found to run parallel in about two-thirds of the cases, suggesting that a flat chylomicron count occurs in the presence of a general defect of absorption.

(vi) It is concluded that some of the fat is normally absorbed without splitting as neutral fat. Patients with sprue may fail to absorb neutral as well as split fat but these absorption defects are distinct and do not respond in the same way to treatment. Failure to absorb neutral fat is more common in the severe cases and responds to liver therapy.

FASTING SERUM LIPIDS AND FAT CURVES

The following account deals with fat curves on a larger number of sprue patients than were available to Aldersberg and Sobotka (1943) and Barker and Rhoads (1937). It includes 31 curves on 16 patients with tropical sprue, and 12 curves on 9 normal controls. Nearly all the sprue patients had two curves, either at different stages of the disease, or with and without substances added to the meal which might influence fat absorption.

MATERIAL AND METHODS

The normal controls were students and ambulant convalescent patients who had diseases not involving the gastro-intestinal tract. All the sprue patients had steatorrhoea and had lost weight ; anaemia and objective tongue signs were less common. They represent early cases of sprue acquired on war time tropical service, the usual duration of symptoms being a few months. Although they differ in this respect from established sprue as seen in patients who have had longer periods in the tropics and then returned to temperate countries, there is no reason to suppose that there is any fundamental difference in fat absorption between early and later sprue. The sprue patients selected for fat curves represent severely ill patients who had lost a lot of weight.

The general procedure was to take a fasting sample of 10 cc. of blood and samples at $2\frac{1}{2}$, 3, $3\frac{1}{2}$ and 4 hours after a standard fatty meal. In the earlier curves, the timing of the after-samples was different, but experience showed that with the meal used, the highest level of serum lipids lay between $2\frac{1}{2}$ and 4 hours, and the times given were then

adhered to. The standard fatty meal consisted of evaporated milk, and contained 18 g. of milk fat. Most other workers have a mixed meal of much higher fat content, about 50 g., but in this study deviations from the accepted procedure were made for the following reasons :—

(i) Evaporated milk gives a homogeneous and accurately reproducible meal, so that it is possible to compare different curves in the same patient.

(ii) The meal had to be tolerable even to the most severe cases of sprue ; even with the small dose of fat used, several of the patients had nausea, and they would certainly have vomited with a larger meal.

(iii) Larger meals give a more prolonged rise in the blood fats, with a peak later than four hours in many cases ; but with this meal, the maximum rise fell within a four-hour period, and the test could be completed within four hours.

(iv) All the patients studied were also on a fat balance, and it was desirable to give them a fat meal which was fairly close to the meal they would have had, so that only small adjustments in the fat intake for the rest of the day were required.

The standard fat meal was given by mouth, and not by duodenal tube, in spite of the known effect of fat delaying gastric emptying. It was found in preliminary experiments that fat given by duodenal tube produced a less definite change in the chylomicron count and blood-fat level than did the same amount of fat given orally. This could be attributed to small intestinal hurry when a quantity of material is introduced into the duodenum. It is of interest that Paterson, Finland and Ballor (1942) found that sulphadiazine given by duodenal tube gave a smaller increase in blood level and urinary output than the same dose given orally.

Total fatty acids, lipid phosphorus, and total cholesterol were determined on a Bloor extract of 5 cc. of serum from each sample. For total fatty acids, the method of Stoddard and Drury (1929) was modified by the use of a Jena sintered glass crucible, porosity 4, in place of a Gooch crucible and filter pad, in filtering the fatty acid suspension. The final titration was done in a 15 cc. long-necked volumetric flask, to minimise absorption of Co_2. Lipid phosphorus was determined colorimetrically on ashed aliquots of Bloor extract. Total cholesterol was estimated by Sackett's method (King, 1945). Relative measurements of the opacity of the sera were made in a Klett-Summersen photo electric colorimeter ; and the chylomicron count was also done.

RESULTS

The observed data in the tables are the total fatty acid (FA) in mEq/L, the lipid phosphorus in mg./100 cc. and the total cholesterol in mg./100 cc.

TABLE XXVIII

Sprue fasting values 26 curves.

Sprue fasting values	Difference between means	Standard error of difference	Coeff. var. (percentage)
Total fatty acids mEq/L ...	11·95	±2·57	21·5
Phospholipid FA ...	4·64	±0·74	16
Cholesterol FA ...	3·10	±0·6	19·4
Neutral FA	4·10	±1·8	42
P/Total ratio	0·397	±0·0557	14
Cholesterol/P	21·9	±4·15	19

Normal fasting values 12 *curves.*

Total FA	12·45	±2·47	19·8
Phospholipid FA ...	5·3	±0·73	13·8
Cholesterol FA ...	3·71	±0·54	14·6
Neutral FA	3·43	±1·63	47·5
P/Total ratio	0·43	±0·04	9·3
Cholesterol	21·8	±2·14	9·8

Standard difference between normal and sprue means.

Total FA	0·87
Phospholipid FA ...	0·26
Cholesterol FA ...	0·19
Neutral FA	0·59
P/Total ratio	0·011

The values given for phospholipid fatty acid and cholesterol fatty acid are calculated on the same assumptions as were made by Peters and Manu (1943) in their extensive study of normal serum lipid values. The neutral fatty acid value represents the difference between the observed total fatty acid and the sum of the calculated values for fatty acids in phospholipid and cholesterol esters.

FASTING VALUES IN NORMAL AND SPRUE PATIENTS

Table XXVIII gives the mean values for the fasting serum lipids in twelve specimens from nine normal subjects. The values are in good accord with the much larger normal series of Peters and Manu (1943). The sprue values given in the same table are derived from 26 specimens from 13 patients; three patients who had received treatment have been excluded. The total fatty acids are on the average lower in sprue, but the difference is not significant on analysis. On the other hand, phospholipid and cholesterol fatty acids are both significantly lower in the sprue patients (P less than 0·02 and less than 0·01 respectively). The average level of calculated fatty acid in neutral fats is higher in the sprue patients, but the difference between it and the small series of normals is not statistically significant; it is significantly higher than the mean level in the normal series of Peters *et al.* (P less than 0·02).

The ratio of phospholipid fatty acid to total fatty acid is lower in the sprue patients, and the difference is significant (P less than 0·01). On the other hand, the ratio of cholesterol to lipid phosphorus is the same as in normal subjects.

TABLE XXIX

Average fat increments in normal subjects.

Subject	Total	Phospholipid	Cholesterol	Neutral
1	4·27	0·52	0·36	3·39
2	2·20	0·44	0·16	1·60
2	0·50	—0·08	0·07	0·50
3	5·31	0·37	0·00	4·93
4	1·00	0·49	0·26	0·25
4	0·49	—0·21	0·16	0·54
5	1·70	0·24	0·01	1·45
6	0·63	0·34	0·18	0·12
7	1·64	—0·02	—0·13	1·79
8	0·50	—0·26	0·00	0·76
9	—0·03	—0·44	—0·10	0·51
Average	1·66	0·128	0·088	1·44

TABLE XXX

Average fat increments in untreated sprue.

Plain meal 13 curves

Name	Total	Phospholipid	Cholesterol	Neutral
Cox ...	1·37	0·45	–1·22	2·14
Thomas ...	0·11	0·44	–0·21	–0·12
Shine ...	4·06	–0·20	0·02	4·24
McKean ...	0·29	–0·10	–0·26	0·65
Parkes ...	–0·22	0·22	–0·24	–0·20
Collier ...	0·52	–0·07	0·04	0·56
Burton ...	0·61	–0·01	0·05	0·57
Parrot ...	0·43	0·02	–0·17	0·58
Sills ...	1·42	–0·58	–0·11	2·11
Oakes ...	0·24	0·49	–0·60	0·35
Kitchener ...	1·48	0·04	–0·06	1·50
Hyde ...	1·03	0·52	–0·03	0·54
Baker ...	0·13	–0·03	–0·35	0·52
Average ...	0·88	0·09	–0·24	1·02

CHANGES IN THE SERUM LIPIDS AFTER THE FAT MEAL

This analysis of the changes after a fatty meal was based not on 'peak values' but on the average increment in three specimens taken between two and four hours after the meal. It will be seen from the curves that the time of the peak after taking the meal is variable even in normal subjects, and a good general picture of the change in the serum lipids cannot be based either on the highest recorded value, which may not be the true peak, or on a single fat estimation at a set time. The period two to four hours was chosen because the highest recorded value for total fatty acids fell within that period in all the normal patients, and in all but 2 of the 31 curves on sprue patients. Both in sprue patients and in normals, the highest recorded value was usually at three to three and a half hours.

TOTAL FATTY ACIDS

Tables XXIX and XXX show the change in total fatty acid, and in the various fractions, after the fat meal in 11 curves on 9 normals, and 13 curves on patients with sprue. From the sprue series, all curves in which glycerophosphate or lecithin was added to the meal, and all treated cases, have been excluded. Both in the normals and in the sprue series, the change in all the blood fat values after the same meal was very variable. One normal subject had a flat curve, and four others had an average increment of less than 1 mEq/L in total fatty acid. In the sprue series, one patient had no increase in total fatty acid, and seven others had an average increase of less than 1 mEq/L. The average increase in total fatty acid in normals was about twice that in the sprue patients.

FATTY ACID FRACTIONS

Increase in the serum phospholipids was much less constant than increase in the total fats, both in normals and in sprue patients, 5 out of 11 normals and 6 out of 13 sprues showed a fall in the phospholipid fraction. One factor in bringing about the variation in the phospholipid response seems to be the fasting value ; on the whole, curves with high fasting values for phospholipid tended to show a drop in the phospholipid after the meal ; but this negative correlation was not close. Since the fasting value for phospholipid was higher in normals than in 'sprue', there may have been some bias in the sprue patients in the form of a phospholipid increase. In terms of averages, however, the sprue patients showed a lesser increase in phospholipid fatty acid than the normals, the increase in both cases being small in relation to the increase in total fatty acid.

In the normal subjects, the meal produced very little change in the serum cholesterol. Two patients showed a fall in serum cholesterol, and the others small increases, the average rise in fatty acids combined with cholesterol being only 0·088 mEq/L. All but 3 of the 13 sprue patients showed a fall in serum cholesterol, and the average decrease in cholesterol fatty acids amounted to 0·242 mEq/L. As one would expect from the comparatively small changes in cholesterol and phospholipid fatty acids, the great part of the increase in serum fats after the meal was due to fatty acid in the form of neutral fat. This applied both to normals and sprue patients, but in the sprue patients the neutral fat increment was usually greater than the total fat increment, owing to the fall in cholesterol fatty acid and often in phospholipid fatty acid. While the average increment in total fatty acid in the sprue patients was only about half that in normals, the increment in neutral fatty acid was practically the same. Only two of the sprue patients failed to show an increase in neutral fatty acid.

In the normal subjects, there was an increase in total fatty acids after the meal, a smaller and less constant increase in phospholipid fatty acid, little change in cholesterol fatty acid, and an increase in neutral fatty acid sufficient to account for the greater part of the total increase in fatty acid. These changes are in general accord with the

results of fat curves in normal persons as summarised by Bloor (1943). In the sprue patients, the increase in total fatty acid was less than in normals, phospholipid fatty acid was also less increased, cholesterol fatty acid showed a definite fall, and the increase in neutral fatty acid was not significantly different from that in normal subjects.

CURVES WITH GLYCEROPHOSPHATE, CHOLINE AND LECITHIN

Verzar and Laszt (1934) showed that the addition of glycerophosphate increased the absorption of fat from intestinal loops in the rat. Preliminary experiments showed that the addition of 10 g. of sodium glycerophosphate to the fatty meal increased the chylomicron count both in normal subjects and in sprue patients. Table XXXI shows the results of paired fat curves, with and without 10 g. of sodium glycerophosphate, in one normal and six sprue patients.

TABLE XXXI

Average fat increments with and without 10 g. sodium glycerophosphate.

Subject	Without				With			
	Total fatty acid	Phospholipid FA	Cholesterol FA	Neutral FA	Total fatty acid	Phospholipid FA	Cholesterol FA	Neutral FA
1	1·46	0·54	—1·22	2·14	1·83	0·23	0	1·61
2	0·11	0·44	—0·21	—0·12	1·85	0·32	0·03	1·50
3	4·06	—0·20	0·02	4·24	0·66	0·24	—0·03	0·44
4	0·29	—0·10	—0·26	0·65	0·31	0·22	—0·13	0·22
5	—0.21	0·22	—0·24	—0·20	2·49	0·39	—0·07	2·16
6	1·14	—0·85	—0·11	2·11	1·58	—0·06	—0·29	1·93
Normal	1·70	0·24	0·01	1·45	3·13	0·31	0·03	2·79

In the normal subject, the curve with glycerophosphate showed a greater increment in total fatty acid, mostly accounted for by an increased increment of neutral fatty acid. Of the sprue patients, three whose fat curve without glycerophosphate was low showed an increase with glycerophosphate, and two others (1 and 6) whose fat curve was fairly normal also showed a small increase with glycerophosphate. Patient 3 differed from others in that his apparent fat absorption without glycerophosphate was unusually high and he showed a smaller increment in the glycerophosphate curve than in the control curve. Glycerophosphate could not be said to have a constant effect on any individual fraction of the fat. Thus there were increases in phospholipid

increment in four curves and falls in two. No very striking changes were noticed in cholesterol, except in one curve where a large decrease in cholesterol without glycerophosphate was absent in the glycerophosphate curve. Patients 2 and 5, who had shown a fall in neutral fatty acid in the curve without glycerophosphate, had increases in neutral fatty acid when glycerophosphate was given; but the other four patients showed a smaller increment in neutral fatty acid in the glycerophosphate curve.

Aldersberg and Sobotka (1943) found that the addition of 10 to 15 g. of 20 per cent. commercial lecithin to a fat meal increased absorption in a small number of normals and sprue patients; they used a single estimation of total blood fat at four hours as their measure of fat absorption. In three curves done with and without lecithin, 10 g. of a preparation found on analysis to contain 50 per cent. phospholipid were used, so that the dosage was a little higher than the actual amount of lecithin given by Aldersberg and Sobotka. Of the three curves done with and without lecithin two showed smaller increase in the blood fats when lecithin was given while the third had a larger increase in the blood fats in the lecithin curve, but one of the patients showed the 50 per cent. increase described by Aldersberg and Sobotka. One patient, who had shown no increase in the fat curve with lecithin, showed a definite increase with sodium glycerophosphate. The dose of lecithin used was small in comparison with the dose of glycerophosphate, and it is possible that a larger dose of lecithin might have given a more definite response. Two curves done with 5 g. of choline afforded no evidence that choline increased fat absorption.

EFFECT OF LIVER TREATMENT

Table XXXII shows fat increments on four patients with severe sprue before and after treatment with an Indian liver preparation, TCF. The dosage used was 4 cc. daily by intramuscular injection, and the preparation was clinically effective, all the patients showing general improvement and definite gain in weight.

TABLE XXXII

Average fat increments before and after treatment with TCF.

Patient	Before				After			
	Total FA.	Phospholipid FA.	Cholesterol FA.	Neutral FA.	Total FA.	Phospholipid FA.	Cholesterol FA.	Neutral FA.
M	0·29	–0·10	–0·26	0·65	0·23	–0·17	–0·03	0·43
H	1·03	0·52	–0·03	0·54	0·80	0·29	–0·07	0·57
K	1·48	0·04	–0·06	1·50	–0·19	–0·16	–0·05	0·02
B	0·13	–0·03	–0·35	0·52	0·40	–0·09	–0·12	0·61

The figures show that this clinical improvement was not attended by any dramatic improvement in the fat curve, in fact three of the four patients showed a smaller increase in total fat. These results are superficially at variance with those of Barker and Rhoads (1937) who found that intensive liver treatment improved the blood fat curve ; but they used a much larger fat meal, and a different liver preparation in a dose of 10 cc. daily, so the two sets of results are not strictly comparable. TCF was the only liver preparation available in adequate amount. It has been shown to be effective in pernicious anaemia, and it was effective clinically in severe sprue, but failed to diminish the steatorrhoea appreciably.

DISCUSSION

It is reasonable to suppose that increase in the blood fats after a fatty meal is mainly related to fat absorption. As a method of studying fat absorption, however, the use of blood fat curves has limitations which must be kept in mind in any interpretation. In the first place, the change in blood fats is likely to reflect the rate at which fat is absorbed, rather than the total amount. Three of the normal subjects had negligible changes in the blood fat, yet none of them had steatorrhoea, so that their ultimate absorption of fat must have been satisfactory. In the sprue patients, too, there was no close correlation between the increment in blood fats, and the total fat absorption as determined by balance experiments. Even if fat is being absorbed at the same rate, the resulting change in the blood fats need not be the same, for fat is removed from the blood-stream into the liver and tissue depots in a quantity and at a rate which cannot be directly determined. The largest change in total fatty acid observed in this series was 5·3 mEq/L, and this could be accounted for by 10 g. of absorbed fat. Most of the increments even in normal subjects were much smaller, so it can be said that removal of fat from the blood occurs in considerable amount during the period of a fat curve, and the observed blood changes are only the resultant of absorbed fat, and fat removed to the liver and depots. A further complication is introduced by the possibility of lipid shifts between red cells and serum. Considerations of this nature serve to explain the great variability in fat curves observed by all workers. The curves reported here are equally variable, but although the ranges overlap widely, it can be said that in sprue patients the rise in serum lipids after a fatty meal is lower than in normals. This finding is in good accord with the more definite evidence of faulty fat absorption which is given by stool analysis. It confirms earlier results done on a smaller number of patients (Barker and Rhoads, 1937 ; Aldersberg and Sobotka, 1943).

Comparison of the partition of the lipids before and after the meal is of interest in relation to the hypothesis put forward by Stannus (1942) to explain the mechanism of faulty absorption in sprue. Stannus accepted the ‘ partition theory ’ of fat absorption (Frazer, 1940), which

claims that fat may be absorbed either as neutral fat in a fine emulsion, or as ' split fat ' in which case phosphorylation may be an intermediate stage in absorption. Stannus suggested that in sprue the essential defect was in phosphorylation, and that the absorption defect would concern only split fats and cholesterol, but would not affect the absorption of unsplit fat. Those results which are in harmony with Stannus' hypothesis can be summarised as follows :—

(i) The fasting values for cholesterol and lipid phosphorus are significantly lower in sprue patients than in normal subjects, the fasting values for neutral fat are normal or even increased in sprue.

(ii) After a fatty meal, the average increase in all lipid fractions is smaller in sprue patients than in normal subjects; the neutral fat increment in sprue is 80 per cent. of the normal average whereas the phospholipid increment is only 60 per cent. of the normal average. The fact that an increase in phospholipids occurs in about half the cases of sprue does not necessarily mean that they are absorbing fat in that form, for phosphorylation of fats occurs in the liver, and Reinhardt, Fishler and Chaikoff (1944) have shown that phospholipid found in the liver can enter the blood-stream, whereas phospholipid formed in the intestine is not available to the blood plasma. On the other hand, the results of blood analysis cannot exclude the theoretical possibility of fat being absorbed as phospholipid, and reconverted to neutral fat in the intestinal wall before entering the chyle. Two of the sprue patients showed a fall in the neutral fatty acid after the fat meal. This might be caused by unusually rapid withdrawal of fat into the depots; but it is also possible that some cases of sprue may have impaired absorption even of neutral fat, as a secondary phenomenon comparable to the general absorption failure which is found in chronic starvation.

(iii) Normal subjects show a negligible change in the serum cholesterol after the fatty meal, in spite of the fact that a fatty meal stimulates an outpouring of bile. In the sprue patients, the fatty meal is followed by a decrease in the serum cholesterol, which can best be explained by failure to reabsorb the cholesterol poured out with the bile.

(iv) The fact that glycerophosphate improved the rate of fat absorption in five out of six sprue patients is consistent with its having improved phosphorylation, although the way in which it does so remains obscure. Improvement in fat absorption with lecithin was not obscured but such an improvement has been observed by Aldersberg and Sobotka (1943). Negative results with choline suggest that lecithin, if active, might owe its activity to its glycerophosphate content, and it is possible that larger doses of lecithin might be more uniformly effective.

The limitations of blood fat curves as a measure of absorption are such that these observations cannot be taken as a proof of the Stannus hypothesis but they lend themselves more readily to explanation on this basis than on any other at present available.

SUMMARY

Total fatty acid, lipid phosphorus and cholesterol were estimated in the serum of 16 patients with tropical sprue, and 9 normal controls. These estimations were repeated at intervals after a standard meal containing 18 g. of fat; in this way, 12 fat curves were done on the normal controls, and 31 on the patients with sprue.

It was found that the fasting level of total fatty acid in sprue did not differ significantly from normal values ; but phospholipid and cholesterol were significantly lower, while the calculated value for neutral fatty acid was higher than normal. After the fatty meal, the total fatty acids in the sprue patients increased less than in normal subjects ; phospholipids showed a smaller increase than neutral fatty acid. The cholesterol, which was little affected by the meal in normal controls, usually fell in the sprue patients. Sodium glycerophosphate, in a dose of 10 g. raised the height of the fat curve in five out of six patients with sprue ; a similar effect was not found with choline or lecithin. No significant change was demonstrated in the fat curve after a period of liver treatment in five patients.

Although the results of serial fat estimations in serum are no doubt affected by metabolic changes not directly concerned with fat absorption, the low fat curve in sprue fits in well with the more direct evidence of faulty fat absorption given by stool analysis. The changes in the different fractions of serum lipids are discussed in relation to Stannus' hypothesis that the absorption defect affects only those lipids which are phosphorylated during absorption. The observed results can be well explained on the basis of this hypothesis, but they cannot be said to contribute directly to proving it.

RESULTS OF BLOOD FAT CURVES IN NORMALS AND SPRUE PATIENTS

The first five columns represent direct observations ; the remaining three columns are calculated on assumptions described in the text. The figures for chylomicron count represent the actual count in a standard field ; that for opacity is the reading on a Klett-Summersen photo-electric colorimeter with a red filter.

TABLE XXXIII

Blood fat curves on normals with oral meal.

Serial No.	Time in hours	Chylomicron count.	Opacity	Total fatty acid (mEq/L)	Lipid phosphorus (mg/100 cc.)	Total Cholesterol (mg/100 cc.)	Phospholipid fatty acid. (mEq/L)	Cholesterol fatty acid. (mEq/L)	Neutral fatty acid (mEq/L)
1.	0	2	...	10·75	8·0	146	4·64	2·73	3·38
	2	128	...	16·85	8·6	154	4·98	2·88	8·99
	3	90	...	15·62	9·7	158	5·62	2·95	7·05
	4	33	...	12·58	8·4	184	4·87	3·44	4·27
	5	10	...	12·05	8 5	133	4·93	2·48	4·64

TABLE XXXIII—(*Contd.*)

Serial No.	Time in hours	Chylomicron count.	Opacity	Total fatty acid (mEq/L)	Lipid phosphorus (mg/100 cc.)	Total Cholesterol (mg/100 cc.)	Phospholipid fatty acid. (mEq/L)	Cholesterol fatty acid. (mEq/L)	Neutral fatty acid (mEq/L)
2.	0	3	29	10·55	7·5	159	4.35	2 98	3·22
	2	125	80	12·19	8·45	169	4.90	3·17	4·13
	3	115	112	13·23	7·8	164	4.53	3·06	5·63
	4	70	73	12·83	8·5	172	4.93	3·20	4·70
	5	60	48	11·63	6·4	158	3.71	2·96	4·96
3.	0	1	35	13·45	9·25	182	5.37	3·40	4·68
	2	20	43	13·45	9 25	195	5.37	3·64	4·44
	2½	20	43	13·45	9·3	195	5.39	3·64	4·42
	3	100	55	12·67	8·75	190	5.08	3·55	4·04
	4	40	74	14·70	8·65	186	5.02	3·48	6·20
4.	0	15	32	11·89	8·5	194	4·93	3·63	3·33
	2	185	89	11·66	8·7	194	5·04	3·63	2·99
	2½	140	93	11·98	8·7	187	5·04	3·50	3·44
	3	105	79	12·87	8·45	187	4·91	3·50	4·46
	4	20	79	12·74	8·25	187	4·78	3·50	4 46
5.	0	...	...	10·96	9·45	189	5·48	3·53	1·95
	2	...	61	11·22	6·75	198	5·07	3·70	2·45
	2½	...	68	11·76	10·9	198	6·32	3·70	1·74
	3	...	51	11·83	8·5	198	4·93	3·70	3·20
	4	...	29	11·18	10·7	199	6·20	3·72	1·26
6.	0	3	...	14·60	10·0	220	5·8	4·12	4·68
	1	5	...	14·74	11·5	220	6·67	4·12	3·95
	2	50	...	16·05	11·5	220	6·67	4·12	5 26
	3	70	...	22·62	10·4	220	6·04	4·12	12·46
	4	50	...	21·05	10·0	220	5·8	4·12	11·13
7.	0	...	...	12·15	10·1	214	5·86	4·0	2·29
	2½	...	...	12·40	9·45	214	5·48	4·0	2·92
	3	...	...	12·70	9·5	214	5·52	4·0	3·18
	3½	...	...	12·15	9·5	214	5·52	4 0	2·63
	4	...	...	13·10	9·95	214	5·77	4·0	3·33
8.	0	...	...	18·85	11·55	254	6·70	4·75	7·4
	2½	...	...	18·15	10·65	250	6·18	4·67	7·3
	3	...	...	18·70	10·85	250	6·29	4·67	7·74
	3½	...	...	19·10	10·95	250	6·36	4·67	8·07
	4	...	...	18·55	10·4	246	6·04	4·60	7·91

TABLE XXXIV

Blood fat curves on normals with duodenal tube meal.

2.	0	3	...	8·92	7·3	200	4·23	3·74	0·95
	2	20	...	9·46	7·3	200	4·23	3·74	1·49
	3	15	...	9·46	7·3	211	4·23	3·94	1·29
	4	10	...	9·32	6·9	200	4·0	3·74	1·58
	5	10	...	9·25	6·9	200	4·0	3·74	1·51

Table XXXIV—(*Contd.*)

The numbers correspond to those already given as 'normal curves', i.e. without duodenal tube, but with the same meal.

Serial No.	Time in hours	Chylomicron count	Opacity	Total fatty acid (mEq/L)	Lipidphosphorus (mg./100 cc.)	Total Cholesterol (mg./100 cc.)	Phospholipid fatty acid (mEq/L)	Cholesterol fatty acid (mEq/L)	Neutral fatty acid (mEq/L)
2.	0	5	...	13·31	10·6	236	6·15	4·42	2·74
	2	10	...	13·31	10·8	250	6·27	4·68	2·36
	3	20	...	14·25	11·45	250	6·64	4·68	2·93
	4	40	...	15·37	12·1	250	7·02	4·68	3·67
	5	30	...	13·60	11·8	236	6·84	4·42	2·34

Table XXXV

Blood fat curves on normals with and without glycerophosphate.

8.	Without								
	0	6	35	11·62	8·3	186	4·82	3·48	3·32
	2	30	52	11·62	8·4	186	4·87	3·48	3·27
	2½	165	75	12·70	8·7	187	5·04	3·50	4·16
	3	60	84	12·78	8·7	186	5·04	3·48	4·26
	4	15	48	14·47	8·8	186	5·10	3·48	5·89
	With								
	0	5	32	13·38	9·1	208	5·28	3·89	4·21
	2	150	107	14·82	9·45	208	5·49	3·89	5·44
	2½	230	174	15·98	9·8	212	5·68	3·97	6·33
	3	140	159	16·60	9·85	208	5·72	3·89	6·99
	4	30	94	16·95	8·25	208	5·37	3·89	7·69

Table XXXVI

Blood fat curves on sprue cases with and without glycerophosphates.

1.	Without								
	0	20	...	9·34	6·6	220	3·82	4·12	1·40
	2	140	...	11·43	7·35	150	4·27	2·80	4·36
	3	175	...	11·32	7·6	145	4·41	2·71	4·20
	4	135	...	9·66	7·6	170	4·41	3·18	2·07
	5	...	...	10·09	7·35	145	4·27	2·71	3·11
1.	With								
	0	15	...	11·72	7·9	208	4·58	3·89	3·25
	2	185	...	12·51	8·1	208	4·69	3·89	3·93
	3	90	...	14·01	8·1	208	4·69	3·89	5·43
	4	80	...	14·11	8·7	208	5·04	3·89	5·18
	5	15	...	12·34	7·5	210	4·34	3·92	4·08
2.	Without								
	0	5	30	12·19	7·6	132	4·41	2·45	5·33
	2	125	91	12·42	7·7	121	4·47	2·25	5·70
	3	50	69	11·19	8·5	115	4·93	2·15	4·11
	4	110	84	11·29	8·9	124	5·16	2·32	3·81
	5	55	57	12·55	9·1	124	5·28	2·32	4·95

TABLE XXXVI—(*Contd.*)

Patient No.	Time in hours	Chylomicron count	Opacity	Total fatty acid (mEq/L)	Lipidphosphorus (mg/100 cc.)	Total Cholesterol (mg/100 cc.)	Phospholipid fatty acid. (mEq/L)	Cholesterol fatty acid. (mEq/L)	Neutral fatty acid (mEq/L)
2.	With								
	0	28	17	12·0	7·45	157	4·32	2·94	4·74
	2	95	51	13·21	8·4	176	4·87	3·29	5·05
	3	185	111	13·10	8·0	155	4·64	2·90	5·56
	4	140	102	14·35	7·6	146	4·41	2·73	7·21
	5	50	44	13·57	7·8	149	4·53	2·79	6·25
3.	Without								
	0	10	54	12·34	9·4	154	5·46	2·88	4·0
	2½	230	188	16·46	8·7	157	5·04	2·94	8·48
	3	250	184	16·51	8·95	155	5·19	2·90	8·42
	3½	160	158	16·15	9·1	155	5·27	2·90	7·98
	4	50	162	16·55	9·2	155	5·33	2·90	8·32
3.	With								
	0	78	124	13·60	7·95	163	4·61	3·04	5·95
	2½	120	124	15·18	9·1	170	5·28	3·18	6·72
	3	165	124	14·22	8·3	157	4·82	2·94	6·46
	3½	155	106	13·38	7·7	157	4·46	2·94	5·98
	4	135	93	14·03	8·6	164	4 98	3·06	5·99
4.	Without								
	0	0	34	7·25	7·0	135	4·06	2·53	0·66
	2	5	37	7·27	6·35	119	3·68	2·23	1·36
	3	25	54	7·71	7·25	121	4·21	2·26	1·24
	4	10	52	7·71	6·9	124	4·0	2·32	1·39
	5	5	36	8·07	6·5	124	3·77	2·32	1·98
4.	With								
	0	10	31	7·27	6·2	128	3·59	2·40	1·28
	2	10	36	7·27	6·65	119	3·85	2·23	1·19
	3	25	40	7·6	6·25	199	3·62	2·23	1·75
	4	50	47	7·88	6·85	126	3·97	2·36	1·55
	5	15	37	7·60	6·75	126	3·91	2·36	1·33
5.	Without								
	0	80	...	15·08	10·4	196	6·04	3·66	5·38
	2½	140	...	15·85	9·8	188	5·68	3·51	6·66
	3	220	...	15·85	9·1	188	5·27	3·51	7·07
	3½	200	...	16·42	8·95	191	5·19	3·57	7·66
	4	80	...	16·30	8·8	191	5·10	3·57	7·63
5.	With								
	0	40	...	12·23	8·2	193	4·76	3·61	3·86
	2½	80	...	12·52	7·9	180	4·58	3·36	4·58
	3	90	...	13·06	8·1	177	4·70	3·31	5·05
	3½	425	...	14·22	8·1	181	4·70	3·38	6·14
	4	80	...	14·15	8·1	175	4·70	3·27	6·18
6.	Without								
	0	5	...	16·51	7·9	191	4·58	3·57	8·36
	2½	30	...	15·36	7·6	177	4·41	3·31	7·64
	3	85	...	15·48	7·9	172	4·58	3·22	7·68
	3½	60	...	17·02	8·35	185	4·84	3·46	8·72
	4	50	...	16·82	8·6	177	4·99	3·31	8·52
6.	With								
	0	10	...	14·11	8·4	202	4·87	3·78	5·46
	2½	150	...	16·49	9·3	202	5·40	3·78	7·31
	3	125	...	16·60	8·55	191	4·96	3·57	8·07
	3½	150	...	16·70	9·35	202	5·43	3·78	7·49
	4	50	...	15·63	8·6	193	4·99	3·61	7·03

Table XXXVII

Blood fat curves on sprue cases with lecithin and choline.

Patient No.	Time in hours	Chylomicron count	Opacity	Total fatty acid (mEq/L)	Lipid phosphorus (mg./100 cc.)	Total Cholesterol (mg./100 cc.)	Phospholipid fatty acid. (mEq/L)	Cholesterol fatty acid. (mEq/L)	Neutral fatty acid (mEq/L)
7.	Without								
	0	8	...	8·25	6·3	119	3·65	2·22	2·38
	2½	20	...	8·25	6·3	114	3·65	2·13	2·47
	3	10	...	8·82	6·3	123	3·65	2·30	2·87
	3½	5	...	8·82	6·1	119	3·54	2·22	3·06
	4	5	...	8·68	6·1	121	3·54	2·26	2·88
7.	*With 5 g. Choline*								
	0	3	...	8·11	6·55	124	3·80	2·32	1·99
	2½	40	...	7·78	5·75	117	3·34	2·19	2·25
	3	50	...	7·96	6·1	113	3·54	2·11	2·31
	3½	50	...	7·96	6·2	117	3·60	2·19	2·17
	4	20	...	7·96	6·2	119	3·60	2·22	2·14
8.	*With Choline*								
	0	58	...	12·38	8·35	175	4·84	3·28	4·26
	2½	46	...	12·63	7·95	178	4·61	3·33	4·69
	3	65	...	13·17	8·55	178	4·96	3·33	4·88
	3½	43	...	13·17	8·50	178	4·93	3·33	4·91
	4	44	...	12·30	8·10	178	4·70	3·33	4·27
8.	*With lecithin*								
	0	50	...	11·43	8·4	174	4·87	3·26	3·30
	2½	97	...	11·43	8·4	168	4·87	3·15	3·41
	3	83	...	11·22	8·4	171	4·87	3·20	3·15
	3½	98	...	11·57	8·6	171	4·99	3·20	3·38
	4	70	..	11·57	8·5	174	4·93	3·26	3·38
9.	*Without*								
	0	15	...	13·61	9·0	191	5·32	3·57	4·72
	2½	70	...	14·47	9·0	180	5·32	3·37	5·78
	3	83	...	13·83	9·05	183	5·35	3·42	5·06
	3½	145	...	13·83	9·05	183	5·35	3·42	5·06
	4	80	...	13·61	9·05	183	5·35	3·42	4·84
9.	*With lecithin*								
	0	5	...	13·50	8·65	184	5·02	3·44	5·04
	2½	40	...	13·83	8·65	184	5·02	3·44	5·37
	3	58	...	15·32	9·95	185	5·19	3·46	6·67
	3½	133	...	15·02	8·75	184	5·08	3·44	6·50
	4	85	...	15·13	8·75	184	5·08	3·44	6·61
5.	*With lecithin*								
	0	20	...	17·18	10·7	204	6·20	3·82	7·16
	2½	195	...	17·18	10·7	199	6·20	3·72	7·26
	3	90	...	16·89	10·3	199	5·97	3·72	7·20
	3½	177	...	16·52	10·3	199	5·97	3·72	6 83
	4	205	...	16·33	9·7	199	5·62	3·72	6·99

Table XXXVIII

Blood fat curves on sprue cases before and after liver treatment.

10.	*Before treatment*								
	0	5	50	13·41	7·35	164	4·26	3·07	6·08
	2½	60	77	13·96	7·05	158	4·08	2·98	6·9
	3	45	98	15·84	7·2	164	4·18	3·07	8·59
	3½	110	97	13·90	8·05	158	4·67	2·98	6·25
	4	80	100	14·93	7·0	158	4·06	2·98	7·89

TABLE XXXVIII—(*Contd.*)

Patient No.	Time in hours	Chylomicron count	Opacity	* Total fatty acid (mEq/L)	Lipid phosphorus (mg./100 cc.)	Total Cholesterol (mg./100 cc.)	Phospholipid fatty acid (mEq/L)	Cholesterol fatty acid. (mEq/L)	Neutral fatty acid (mEq/L)
10.	*After treatment*								
	0	45	...	13·73	8·6	163	4·98	3·05	5·70
	2½	15	...	13·80	7·75	159	4·49	2·98	6·33
	3	70	...	14·01	8·25	159	4·78	2·98	6·25
	3½	120	...	13·80	8·45	159	4·91	2·98	5·91
	4	60	...	13·80	8·25	162	4·78	3·03	5·99
11.	*Before treatment*								
	0	5	22	11·09	6·85	177	3·97	3·31	3·81
	2½	80	79	11·63	7·4	170	4·29	3·18	4·16
	3	70	78	12·24	7·65	174	4·44	3·26	4·54
	3½	100	70	11·84	7·75	176	4·49	3·29	4·06
	4	...	76	12·28	7·8	176	4·53	3·29	4·46
11.	*After treatment*								
	0	2	...	10·71	7·75	164	4·49	3·07	3·15
	2½	63	...	11·48	7·85	160	4·56	2·99	3·93
	3	80	...	11·48	7·95	160	4·62	2·99	3·87
	3½	30	...	11·48	8·3	162	4·82	3·03	3·63
	4	25	...	11·57	8·45	162	4·91	3·03	3·63
12.	*Before treatment*								
	0	5	...	10·74	6·5	131	3·77	2·45	4 52
	2½	100	...	10·54	6·55	113	3·80	2·11	4·63
	3	105	...	11·08	6·3	116	3·66	2·17	5·25
	3½	140	...	11·08	6·5	111	3·77	2·08	5·23
	4	100	...	10·42	6·55	109	3·80	2 04	4 58
12.	*After treatment*								
	0	10	...	11·12	6·7	125	3·88	2·34	4·90
	2½	35	...	11·25	6·45	125	3·74	2·34	5·17
	3	45	...	11·30	6·5	118	3·77	2·21	5·32
	3½	40	...	11·48	6·5	118	3·77	2·21	5·50
	4	40	..	11·79	6·6	120	3·83	2·25	5·71
4.	*After treatment*								
	0	15	...	12·49	7·85	186	4·55	3 48	4·46
	2	60	...	12·62	7·65	187	4·44	3·50	4·68
	3	125	...	13·03	7·40	180	4·29	3·37	5·37
	4	75	...	12·52	7·60	186	4·41	3·48	4·63
	5	20	...	12·52	7·75	178	4·49	3 33	4·70

TABLE XXXIX

Miscellaneous sprue curves.

2.	*After nicotinic acid plus riboflavin*								
	F	8	33	10·43	8·05	177	4·67	3·32	2·44
	2½	35	49	10·63	8·1	169	4·70	3·16	2·77
	3	50	49	10·39	7·75	169	4·49	3·16	2·74
	3½	20	37	9·92	7·6	170	4·41	3·18	2·33
	4	20	44	9·92	8·25	172	4·78	3·22	1·92
13.	*After full treatment*								
	F	4	30	11·75	6·2	153	3·59	2·86	5·30
	2	75	97	13·90	7·95	148	4·62	2·77	6·51
	3	120	95	14·16	5·7	148	3·30	2·77	8·09
	4	80	49	13·28	4·9	147	2·84	2·75	7·69
	5	60	44	12·58	4·9	147	2·84	2·75	6·99

TABLE XXXIX—(*Contd.*)

Patient No.	Time in hours	Chylomicron count	Opacity	Total fatty acid (mEq/L)	Lipid phosphorus (mg./100 cc.)	Total Cholesterol (mg./100 cc.)	Phospholipid fatty acid (mEq/L)	Cholesterol fatty acid (mEq/L)	Neutral fatty acid (mEq/L)
14.	*No treatment*								
	F	12	...	9·47	6·3	216	3·65	4·04	1·78
	2	35	...	8·78	7·2	181	4·18	3·38	1·22
	3	32	...	10·21	7·2	196	4·18	3·67	2·36
	4	34	...	9·76	7·2	182	4·18	3·38	2·20
	5	...	...	9·15	7·0	174	4·06	3·26	1·83
15.	*After liver treatment*								
	F	7	47	22·07	11·6	216	6·74	4·04	11·29
	2½	60	97	22·55	12·0	212	6·96	3·97	11·62
	3	75	82	22·42	12·6	206	7·32	3·86	11·24
	3½	125	70	23·73	12·5	214	7·26	4·00	12·47
	4	40	70	23·01	12·5	220	7·26	4·12	11·63
16.	*After liver treatment*								
	F	1	32	9·49	5·8	116	3·36	2·17	3·96
	2½	45	36	9·63	5·4	118	3·13	2·20	4·30
	3	55	45	11·32	5·5	118	3·19	2·20	5·93
	3½	35	33	10·13	5·7	113	3·31	2·11	4·71
	4	46	45	...	5·5	113	3·19	2·11	...

TABLE XL

Additional fasting values.

6	...	10	...	14·32	10·1	199	5·86	3·72	4·74
8	...	15	...	10·71	8·0	154	4·64	2·88	3·19
9	...	8	...	13·71	9·65	197	5·60	3·69	4·42
15	...	20	...	30·75	15·2	233	8·81	4·36	17·58
15	...	...	...	26·20	14·9	236	8·64	4·42	13·14

ABSORPTION OF NON-FATTY SUBSTANCES

Although the chief object of the biochemical investigation was to obtain data on fat absorption in an adequate number of early cases of sprue, yet a certain number of observations were also made on the absorption of substances other than fats. Most of this concerns the absorption of glucose, as judged by the glucose tolerance test ; but a few observations are included on the absorption of iron, amino-acids, and iodides, and some information bearing on absorption has also been obtained from nitrogen and electrolyte balances.

BLOOD SUGAR CURVES

It is generally recognised that a flat type of blood sugar curve is common, though not universal, in sprue patients after a glucose meal. This flat curve is caused by impaired absorption of glucose, rather than

by any alteration in carbohydrate metabolism, since intravenous injection of glucose gives a normal or even a high blood sugar curve (Fairley, 1936). Therefore, the main object was not the accumulation of further data on glucose absorption itself, but an assessment of whether there was any relationship between the glucose and the fat absorption defects. The material for this purpose consists of 70 curves done on 27 patients with sprue ; specimens were taken at half-hourly intervals up to two hours after giving 50 g. glucose, and the analysis of the results is based on the difference between the fasting values and the highest observed blood-sugar figure within one hour of the meal. Peaks of blood-sugar occurring later than one hour have not been included, since they are in themselves an abnormality. Such peaks were observed in 9 out of 25 untreated patients.

Table XLI shows the mean fasting values of blood sugar in 15 untreated patients and in 15 patients who had received treatment with parenteral liver.

TABLE XLI

Fasting blood sugar in untreated sprue and after parenteral liver treatment.

	Untreated (15 cases)	Treated (Parenteral liver) 15 cases
Mean	85·8 mg./100 cc.	94·5 mg./100 cc.
Standard difference ...	±10·2 „	±7·5 „
Range	71–100 „	83–111 „
Difference of means ...	8·7	
Standard error of difference ...	3·27	

The fasting value is significantly lower in the untreated group (P less than 0·02). Serial observations on individual cases showed that increase in the fasting value of blood sugar occurred within two weeks of beginning liver therapy. The low fasting blood sugar level in untreated sprue is probably analogous to that found in starvation, and is brought about either by actual restriction of the carbohydrate in the diet, or by failure to absorb part of the dietary carbohydrate.

The distribution of the maximum blood-sugar increment in the first hour in 25 untreated patients with sprue is shown in Table XLII.

TABLE XLII

Frequency distribution of 25 *untreated cases of sprue with reference to the maximal blood-sugar increment after* 50 *g. glucose.*

	Blood Sugar Increment (mg./100 cc.)				
	Less than 20	20–30	30–40	40–50	Over 50
Number of cases	6	4	6	3	6

Sixteen of the patients had a rise in the blood-sugar of less than 40 mg./100 cc. and 10 of these had less than 30 mg./100 cc. On the other hand, six patients had curves which would be generally accepted as 'normal'. The incidence of 'normal' and 'low' curves was found to be quite unrelated to the degree of the fat absorption defect, as judged by fat balance experiment. Table XLIII gives the figures on which this statement is based.

TABLE XLIII

Correlation table of percentage fat absorption, and maximum blood-sugar increment after 50 g. glucose.

Maximum blood sugar increment (mg./100 cc.)	Percentage Fat absorption			
	Less than 70	70–80	80–90	Total
Less than 30	4	3	6	13
30–40	2	5	6	13
Over 40	4	5	6	15
Total	10	13	18	41

It will be seen that 'normal' sugar curves may be found in patients with a severe fat absorption defect, while other patients with a mild fat absorption defect may have a low blood-sugar curve. Three patients (not included in the table) whose fat absorption had improved with treatment to normal levels (over 90 per cent.) were all found to have normal blood sugar curves. In interpreting these results it must be borne in mind that fat balance measures total fat absorption, whereas a glucose tolerance curve measures only the rate of sugar absorption. Although the incidence of definitely abnormal sugar curves is less than that of steatorrhoea, it is quite possible that the glucose absorption defect appears concurrently with the fat absorption defect, but that it cannot be detected by the tolerance curve method. In this connection, it may be pointed out that fat curves of normal type can be obtained in patients whose impaired fat absorption is well attested by heavy steatorrhoea.

A limited number of observations were also made on the absorption of simple water-soluble substances. Although glucose is also water-soluble, there is strong evidence of the existence of a special phosphorylation mechanism for its absorption, and it seemed important to find out whether in the early stages of sprue the absorption defect was limited to fat and glucose, or whether there was a general impairment of absorption. Most of the observations were made on iron absorption, using serum iron curves.

SERUM IRON VALUES

Table XLIV shows the serum iron values in six patients at two, three and four hours after a dose of $7\frac{1}{2}$ grains ferrous sulphate, compared

with the fasting value. The percentage fat absorption and the maximum blood-sugar increment after 50 g. glucose are also shown.

TABLE XLIV

Serum iron curves with blood sugar increment and percentage of fat absorption.

Patient No.	Serum iron (mg./100 cc.)				Blood sugar increment (mg./100 cc.)	Percentage fat absorption
	Fasting	2 hours	3 hours	4 hours		
1	93	83	297	137	45	63
2	102	230	...	143	42	81
3	113	237	283	230	20	85
4	94	286	450	462	37	78
5	90	...	...	232	38	70
6	100	115	110	127	23	56
6 (after liver)	166	242	252	275	49	74

All the curves showed an increase in the serum iron of 100 per cent. cc. or more except the first curve on patient No. 6 who had an almost flat curve. After three weeks of parenteral liver therapy, this patient's serum iron showed a rise of 109 per cent. after iron, and concurrently his blood sugar curve rose to within normal limits, and his fat absorption improved. Comparison with blood sugar curves and fat absorption figures in the other patients showed that there could be a good rise in the serum iron curve when fat absorption is poor, and also when the blood sugar curve is abnormally low.

The absorption of iodide in eight patients was also tested, by determining the time taken for iodide to appear in the saliva after the ingestion of 3 grains of sodium iodide ; the times ranged from 5 to 27 minutes, all within the normal range. Dixon (1946) found that the blood amino-acid rose in the normal way after the ingestion of 25 g. of glycine by four convalescent sprue patients. Similar observation was made in one patient with definite early sprue. Thaysen (1932) found that in most cases of idiopathic steatorrhoea the faecal nitrogen was within normal limits; in one of his nine patients there was an abnormally large loss of nitrogen in the faeces. He concludes that in general protein absorption is not impaired in sprue. In observations on electrolyte changes in sprue it was found that formed sprue stools contain no excess of chloride ; their content of sodium is rather high, but that is more likely to be due to soap formation than to any defect in sodium absorption. On the other hand, in phases of watery diarrhoea the stools contain large amounts of sodium and chloride, and raising the salt content of the diet increases the loss of sodium and chloride in the stools.

In general, it may be said that no evidence was found of a generalised absorption defect in the majority of cases of sprue, including some

with heavy steatorrhoea and a flat glucose tolerance curve. Exceptional cases do show impaired absorption of substances other than fat and glucose, and this is especially so when watery diarrhoea is present.

NITROGEN METABOLISM IN SPRUE

The literature on sprue has so far dealt mainly with fat and carbohydrate metabolism in this disease. It, therefore, seems important that as thorough a study as possible should be made of the metabolism of 'nitrogen' (otherwise protein). This importance becomes greater when it is considered that fat and carbohydrate, either or both play mainly the role of an energy source ; whereas that played by protein is largely structural or functional. Therefore, any gross error in protein metabolism is of considerable pathological significance.

A study of this type falls under two headings :—

(i) *Absorption :* Examination of faecal nitrogen in relation to dietary nitrogen to ascertain the degree of absorption.

(ii) *Utilisation :* Examination of urinary nitrogen and its correlation with absorbed nitrogen thus showing whether a state of negative or positive balance exists.

All the patients studied were in remission phase of the disease except one who was studied in relapse and remission. Diets[2] used were as follows :—

Diet	Protein (High Grade)	Carbohydrate	Fat
Diet A ...	140-160 gms	250 gms	90-96 gms
Diet B ...	140-160 gms	215 gms	66-69 gms

A difficulty encountered was the capricious nature of the sprue appetite, tending to variations in the day-to-day intake and also variations between the average intake of different patients.

SPECIMEN COLLECTION

(i) *Urine :* Urinary output was collected and measured over three or four-day periods. After micturition the urine was transferred to *ghee* tins and preserved under a layer of kerosene. The classical fixation with mineral acid was not practicable owing to the shortage of AR quality acid. However, a check made with urine preserved with kerosene and urine fixed with 10 per cent. W/V H_2SO_4 showed the ammonia loss to be within the biological error of these experiments.

(ii) *Faeces :* The periods of collection were similar to those of urine (three or four day periods); stools after passage were transferred to tin pans, and formalised to inhibit bacterial action.

[2] Values for protein content of foods were taken from *Chemical Composition of Foodstuffs* (McCance and Widdowson, 1940). The protein fraction of these diets was 'high grade' consisting of meat, fish, eggs and milk.

NITROGEN ESTIMATION

(i) *Urine :* The volume of the composite sample was measured and the whole well mixed. 2 cc. was removed and digested with 5 cc. (concentrated H_2SO_4 plus 2 per cent. sodium selenite).

The digest was made to a volume of 50 cc. and nitrogen estimation made on 10 cc. of the final solution. The micro-kjeldahl's method was used employing N/50 acid and back titrated with N/100 NaOH using methyl red as indicator.

(ii) *Faeces :* The pooled specimens of faeces were thoroughly mixed and macerated to obtain homogenity. A 10 grain sample was accurately weighed and mixed thoroughly with 12 cc. of water. 10 cc. concentrated H_2SO_4 was slowly added with stirring and the whole brought to the boil. By this method, a dark brown homogenous mixture was obtained. The mixture was diluted to 100 cc. and 10 cc. digested in the same manner as for urine. The digest was diluted to a volume of 50 cc. and a micro-kjeldahl estimation made on 10 cc. of the solution.

RESULTS

These are tabulated in Tables XLV and XLVI. In view of the biological error, results are only expressed to the first decimal place.

DISCUSSION

Nitrogen Absorption : Table XLV represents the analyses of two, three and four-day pooled faecal specimens, compounded into twelve and fourteen-day periods and the results expressed as an average per twenty-four hour period.

The average of such long periods was considered necessary in order to obtain a representative value for a twenty-four hour stool; the use of markers over shorter periods being unsatisfactory especially with soft or liquid stools.

The legitimate assumption was made that any assay of faecal nitrogen can be interpreted as an assay of protein.

Taking the upper limit of normal faecal nitrogen as 1·5 g. per 24 hours, it will be seen that of the 20 studies made, some 14 are above this level, ranging in value from 1·6 g. to 4·0 g. per 24 hours (average 2·4 g.).

Assuming a normal protein intake (about 16 g. N_2) these faecal nitrogen figures do not represent a significant loss. However, in the untreated phase of this disease with anorexia and diarrhoea, the protein intake may fall to such a level that the net nitrogen absorption may well fall below the critical value of 6 g. per day, thus producing a negative balance. Except for examples 19 and 20, there appears to be no significant relationship between faecal nitrogen and nitrogen intake.

TABLE XLV

Nitrogen estimation average per day. (Absorption)

Case	Experiment Number	Period (days)	Faecal weight g.	Faecal N_2 g.	Percentage of faecal weight g.	Diet N_2 g.
1	1 2	12 12	153 130	2·2 1·6	1·5 1·2	23 20
2	3 4	12 12	178 186	2·5 2·2	1·3 1·2	24 24
3	5	12	85	1·3	1·4	19
4	6	12	187	2·0	1·1	22
5	7 8 9	14 12 12	547 315 287	4·0 3·6 2·9	0·8 1·2 1·0	23 23 22
6	10 11	12 12	140 240	1·3 3·0	0·9 1·2	25 23
7	12 13 14	12 12 12	223 282 315	2·4 2·6 2·3	1·1 0·9 0·7	20 20 18
8	15 16	12 8	99 153	1·0 1·8	1·0 1·2	22 18
9	17 18	12 12	133 147	1·1 1·6	0·8 1·1	25 26
10	19 20	11 12	144 130	1·3 0·6	0·9 0·46	15 12

The general rise in faecal nitrogen could be attributed to any of the following causes :—

(i) Primary failure to absorb ingested nitrogen.

(ii) Increase of intestinal bacteria growing on the dietary substrate.

(iii) Intestinal irritation giving rise to increase nitrogenous secretions and casting of epithelial cells.

The first cause can be excluded as it will be observed that nitrogen excreted is roughly related to the weight of stool; the greater that weight the larger the nitrogen output, and vice versa. Further the actual percentage nitrogen in the stool only varies between 0·7 and 1·5 per cent. If failure of absorption had occurred and persisted, the stools of smaller weight would be expected to contain a considerably high percentage of nitrogen than that actually found.

TABLE XLVI

Nitrogen estimation expressed as average per 24 hours. (Utilisation)

Case	Experiment Number	Period (days)	Faecal N_2 g.	Urinary N_2 g.	Dietary N_2 g.	Nitrogen retention g.
1	1	11	1·2	8·0	15·8	6·6
	2	12	0·6	6·7	11·5	4·2
	3	12	1·6	8·5	16·0	5·9
2	4	12	2·4	9·0	19·16	8·2
	5	12	2·6	11·2	18·0	4·2
	6	12	2·3	8·8	19·5	8·4
3	7	14	4·0	16·5	23·5	3·0
	8	12	3·6	20·8	23·3	−1·1
	9	12	2·9	15·0	22·1	5·1
4	10	12	1·3	14·8	25·0	8·9
	11	8	3·4	14·2	24·5	6·9
5	12	3	5·6	13·0	17·6	−1·0
	13	3	5·9	10·8	23·3	6·6

The data available does not offer an explanation as to which of the causes is operative. However, the clinical observation that diarrhoea in sprue is amenable to sulphaguanidine therapy suggests increased bacterial action.

This from a metabolic standpoint, is of no significance because whichever of these processes is operative the net result still represents a nitrogen loss.

Utilisation : Table XLVI gives results of nitrogen balance experiments on five cases. These results have been compounded and arranged in a similar manner to those in Table XLV.

With the exception of experiments 8 and 12 to be discussed later, the salient feature is the retention of nitrogen by all cases. This indicates that at some period prior to admission to hospital a negative balance existed. All these cases had a previous history of several months' diarrhoea and anorexia. It is, therefore, reasonable to assume that this state of negative balance resulted from an elevated faecal nitrogen and lowered protein intake. Experiment 12 demonstrates this point ; the balance experiment was made on a patient undergoing a relapse accompanied by diarrhoea and anorexia.

Experiment 8 was a study on a case rapidly recovering, i.e. in marked remission, with elevated faecal nitrogen, a negative balance and high urinary nitrogen. The patient was eating the full diet of carbo-

hydrate and fat. The high urinary nitrogen and negative balance may indicate in this period relatively poor utilisation of fat and carbohydrate with an increased metabolism of protein.

The general results of these experiments indicate a good absorption, retention, and turnover of nitrogen. This is especially apparent in cases 3 and 4 who had a higher average protein intake. This would suggest that from the dietary standpoint as high a protein intake as possible is desirable in sprue cases.

SUMMARY

(i) Twenty experiments on faecal nitrogen in sprue showed an elevation in 70 per cent.

(ii) This elevation is considered only to be significant in conjunction with a low protein intake.

(iii) The increased nitrogen level is probably the result of increased bacterial action.

(iv) Nitrogen balance experiments on five cases showed good retention and turnover, indicating the existence of a previous negative balance.

(v) The satisfactory absorption of nitrogen lends support for a high protein diet in these cases.

SALT DEFICIENCY IN SPRUE

Hypotension defined as a blood pressure below 100/70 mm. Hg. has occurred in 66 out of the total of 680 cases reviewed in this chapter. These cases of sprue have all been of relatively short duration —less than a year. The hypotension has occurred in the majority of instances in those who are in the relapse phase of the disease with prolonged diarrhoea, vomiting and anorexia. These have all shown clinical evidence of dehydration and peripheral circulatory failure. In acute sprue, as seen in India during World War II, this is the group from which the occasional fatal case was drawn.

It is particularly relevant, therefore, to find some adequate explanation for the development of this syndrome.

Since these symptoms have so much in common with those of salt deficiency syndromes experimentally produced, an investigation into this condition was undertaken.

METHODS

The following analytical methods were used :—

Serum sodium	... Uranyl zinc acetate precipitation.
Serum potassium	... Cobaltonitrite precipitation.
Serum chloride	... Volhard-Harvey titration.
Blood urea	... Urease-Nesslerisation.
Plasma volume	... Vital red method.

Chloride was determined in urine and stools by the open Carius method ; sodium and potassium were determined on ash extracts of stools and urine.

GENERAL CLINICAL FEATURES

The ten patients investigated were all suffering from tropical sprue contracted during their period of service in the India-Burma theatre. All had steatorrhoea, fat accounting for more than 30 per cent. of the dry stool weight. All had lost 10 kg. or more of body weight.

Several had periods of remission during their illness which in all was less than a year. Evidence of glossitis was common but inconstant. Anaemia was not marked. Anorexia and diarrhoea were marked symptoms. Abdominal distension was variable.

These cases were selected for investigation as low blood pressure in conjunction with the other symptoms and signs described above formed the picture of acute severe sprue. Clinical evidence of dehydration and peripheral circulatory failure such as flaccid wrinkled skin, pallor, collapsed superficial veins, etc., was present in these cases.

LABORATORY FINDINGS

In Table XLVII are given the results of the estimation of plasma volume and haematocrit, and of serum sodium, chloride and potassium in ten patients. In the calculation of the plasma volume per kg. the patients' actual weight at the time of estimation has been used. If the normal body-weight had been used the values would have been lower by 10 per cent. or more.

TABLE XLVII

Results of the estimation of plasma volume and haematocrit, and of serum sodium, chloride and potassium in ten patients of sprue.

Patient	Serum sodium		Serum chloride		Serum potassium		Blood Urea mg./100 cc.	Plasma volume litres	Plasma volume cc./kg.	Hæmatocrit percentage	Blood pressure mm. Hg.
	mg./100 cc.	mEq/L	mg./100 cc. as NaCl	mEq/L	mg./100 cc.	mEq/L					
1	300	130	580	99	...	...	60	2·5	61	37	90/52
2	300	130	545	93	16	4·1	42	3·0	52	36	74/45
3	320	139	608	104	...	...	45	2·2	41	40	88/56
4	310	135	571	98	15	3·8	40	2·2	40	44	92/68
5	315	137	573	98	18	4·6	30	1·9	42	50	96/54
6	304	132	664	96	...	...	50	1·7	34	46	100/60
7	278	121	517	88	20	5·1	45	2·0	44	40	94/54
8	314	136	573	98	22	5·6	54	2·5	46	43	94/60
9	312	135	566	97	20	5·1	29	2·4	46	46	110/68
10	258	112	515	88	20	5·1	36	2·1	53	42	100/70

Seven of the patients had a plasma volume of less than 2·5 litres, and two of them less than 2·0 litres. Five of the patients had a plasma volume of less than 45 cc./kg. The haematocrit readings lay mostly between 40 and 46 per cent. ; but one high value of 50 per cent., and two low values of 36 and 37 per cent., were observed. Later estimations of the haematocrit percentage showed that these normal values did in fact represent a moderate haemo-concentration, for when the plasma volume rose with therapy the haematocrit percentage fell to values just below the usual normal limits.

The serum sodium values were uniformly low, ranging from 258 mg./100 cc. to 320 mg./100 cc. (112 to 139 mEq/L). A control series of five sprue patients with gross steatorrhoea, but with a normal blood-pressure, gave values for the serum sodium ranging from 318 mg./100 cc. to 354 mg./100 cc. Moreover, normal values were found for the serum sodium in four of the patients reported in Table XLVII, on whom it was possible to obtain a blood sample after recovery. The serum chlorides were also low, but less markedly so than the serum sodium (range 515 mg./100 cc. to 608 mg./100 cc. or 88 mEq/L to 104 mEq/L). The serum potassium was done in seven patients, and in none of them did it exceed the upper limit of normal. The highest blood urea was 60 mg./100 cc. and in five other patients the blood urea was over 40 mg./100 cc.

This group of observations indicated that in these patients hypotension and circulatory failure were associated with a low serum sodium and chloride, and less constantly with a low plasma volume. They gave no evidence as to whether the observed sodium deficiency was caused by inadequate intake or loss of electrolytes, or whether diminished activity of the suprarenal gland might be responsible for the hypotension, as was suggested by Thaysen (1932). It was found in the later patients of the series that treatment with salt, either by mouth or intravenously, was followed by the disappearance of the circulatory collapse, and the serum sodium rather slowly returned to normal levels. It was also found that the excretion of chloride in the urine was low, of the order of 3 g. to 5 g. per day, but that chlorides were never absent from the urine. The urine and faeces of patient No. 10 were collected over a fifteen day period after his admission and again for a three-day period after he had completely recovered from dehydration but while he was still passing large amounts of fat in the faeces. Tables XLVIII to LI give the results of blood, urine, and stool analysis, and the mineral intake and output for corresponding periods.

The blood estimations showed a low serum sodium which rose rapidly when salt was added to the diet. The serum chloride was not so low as the serum sodium initially, and it rose to within normal limits more rapidly. The initial plasma volume was lower than the value obtained after recovery, but the difference was not a striking one. The haematocrit percentage fell when dehydration was corrected, and later rose again to a normal value as the patient's general state improved. The blood urea during the dehydration period lay within the normal range, but was higher than after recovery. Kirsner, Palmer and Knowlton (1943) comment on the fact that blood urea

TABLE XLVIII

Blood analysis in patient No. 10.

Date	Serum sodium		Serum chloride		Blood urea mg./100 cc.	Plasma volume litres.	Haematocrit percentage.
	mg./100 cc.	mEq/L.	mg./100 cc.	mEq/L.			
22 September	258	112	...	...	36	2·1	42
23 September	296	129	515	88	32	...	...
27 September	320	139	620	106	40	...	...
29 September	310	135	612	104	45	...	...
1 October	...	...	...	...	...	2·5	34
1 November	337	146	615	105	24	2·7	41

Note : The serum potassium on 23 September was 20·2 mg./100 cc. The alkali reserve on 29 September was 47·3 vol./100 cc.

TABLE XLIX

Urine analysis in patient No. 10.

Period	Volume	Specific Gravity	Sodium		Chloride		Potassium		Urea g.	Urea clearance percentage of average normal
			g.	mEq/L	g.	mEq/L	g.	mEq/L		
I	3,138	1,012	0·14	6·1	4·7	132	0·12	3·1	57	80
II	4,415	1,012	0·31	13·5	14·6	412	1·06	27·2	59	63
III	3,000	1,010	0·21	9·1	10·2	288	0·68	17·4	40	46
IV	4,830	1,006	1·03	44·8	8·6	242	0·65	16·7	44	50
V	8,640	1,007	1·08	47·0	9·2	259	0·75	19·2	97	85
After	7,570	1,031	17·5	762 0	30·5	860	3·0	77	53	86

Note : All periods are of three days, and the figures for sodium, chloride, potassium and urea represent the total excretions in each period. Periods I to V are consecutive starting from 22 September, the after-period was the three days 12 to 14 November at which time the patient had a normal blood pressure, but was still passing fatty stools.

TABLE L

Faecal analysis in patient No. 10.

Period	Wet weight g.	Dry weight g.	Total fat g.	Sodium		Chloride		Potassium	
				g.	mEq/L	g.	mEq/L	g.	mEq/L
I ...	3,520	239	87	4·6	200	1·2	34	1·0	25
II ...	9,155	277	118	8·9	387	8·1	228	1·8	46
IV ...	3,550	136	71	3·4	148	2·1	59	2·0	51
V ...	910	113	49	0·8	35	0·4	11	2·8	72
After ...	1,225	265	96	0·5	29	0·03	1	4·1	105

TABLE LI

Intake and output of electrolytes in patient No. 10.

Period	Intake						Output					
	Sodium		Chloride		Potassium		Sodium		Chloride		Potassium	
	g.	mEq/L	g.	mEq/L	g.	mEq/L	g.	mEq/L	g.	mEq/L	g.	mEq/L
I	10·1	440	16·7	470	10·3	264	4·6	206	5·9	166	1·1	29
II	27·8	1,210	43·0	1,210	9·9	254	9·2	401	22·7	640	2·9	73
III	20·0	870	31·2	852	7·9	206	9·2	401	14·2	401	5·6	143
IV	12·8	557	20·0	563	4·2	108	4·4	193	10·7	301	2·7	68
V	10·9	474	17·9	504	8·8	226	1·9	82	9·6	270	3·6	91
After	18·2	792	28·4	800	11·0	282	18·0	791	30·5	861	7·1	182

Note : The potassium intake was derived entirely from the food, and its variability was due to the patient having been unable to take different items of measured diet at different times. The sodium and chloride were derived partly from the diet, and partly from supplements of sodium chloride, to the amount of 5 g./day in period I, 25 g./day in period II, 15 g./day in period III, and 10 g./day in periods IV and V and the after-period.

may show little increase in moderate degrees of salt deficiency. However, the urea clearance (Table XLIX) was depressed at the time when the blood urea was highest, and the three day output of urea also fell. Comparison of the results in Table XLVIII with the clinical data in the appended case report on the anomalous blood findings was attended by only partial clinical improvement. The pulse rate fell, the blood-pressure rose, and the peripheral circulation improved. There was some gain in weight, but the patient continued to pass very large fluid stools, his appetite was poor, and he felt no better. It was obvious that salt deficiency had been responsible for only a part of the complex clinical picture and rapid improvement in his general conditions occurred only after he was treated with sulphaguanidine and parenteral liver.

Mineral Balance and Excretion (Table XLIX-L) : There was retention of sodium, chloride and potassium throughout the first observation period of fifteen days. In the case of sodium and chloride, this occurred on dietary intakes varying from less than 10 g. to more than 20 g. of sodium chloride per day, even though quite abnormal amounts of sodium and chloride were being lost in the stools.

The retention of sodium and chloride was accompanied by a rise in their serum concentrations. In the after-period of three days, the patient was in sodium balance, and was excreting rather more chloride than he took in ; there was still a retention of potassium, which may have been related to the fact that he was still putting on weight rapidly. Although the dietary intake of sodium and chloride, when expressed in

milli-equivalents, was approximately equal, more sodium than chloride was retained, except during period I, when the patient was on a diet containing less than 10 g. of salt per day. This suggests that in the period before observations, when salt deficiency was actually developing, loss of sodium had exceeded loss of chloride. Even in the observation period loss of sodium in the stools was much greater than loss of chloride and normal intestinal secretion is known to contain more sodium than chloride (Gamble, Fahey, Appleton and MacLachlan, 1945). The total loss of sodium and chloride in the stools was greatly in excess of the negligible amounts found in normal stools. Even in the after-periods, although chloride was practically absent from the stools, they still contained 0·5 g. of sodium in three days at this stage. The stool was still bulky and contained much fat, but the ratio of dry to wet weight was within normal limits. The greater loss of sodium than of chloride in the stools was clearly reflected in the urinary excretion of these ions. In the first observation period, the urine contained only 6·1 mEq/L of sodium in three days, whereas in the same time 132 mEq/L of chloride was excreted. After some days on diet with added salt, the chloride output in the urine was still more than five times greater than the sodium output. Only in the after-period were sodium and chloride excreted in equivalent amounts. These findings indicate that salt deficiency in this patient was complicated by acidosis. The kidneys conserved base rigidly, but continued to excrete chloride in significant amounts. Further evidence of acidosis may be found in the alkali reserve of 47·3 vol./100 cc. and in the finding of 113 mEq/L of ammonia plus titratable acidity) in one twenty-four-hour specimen of urine.

DISCUSSION

The clinical and laboratory findings in these patients are those of dehydration due to salt deficiency. Similar episodes of dehydration are not uncommon in coeliac disease. Prunty and Macoun (1943) described a case of non-tropical steatorrhoea with hypotension and low serum sodium and chloride. The comparative frequency of salt deficiency as a complication of tropical sprue does not seem to have been appreciated, for electrolyte studies in this disease have been almost confined to calcium and phosphorus metabolism.

The chief cause of salt deficiency in these patients is almost certainly the loss of sodium and chloride in the bulky, often fluid stools. It may be left an open question whether the sodium and chloride in the stools represent unabsorbed dietary salt or intestinal secretion which has not been reabsorbed in the usual way. The greater loss of sodium than of chloride suggests that intestinal secretions form a large part of the fluid stool. On the other hand, increasing the intake of saline fluid in patient No. 10 was followed by a three-fold increase in the bulk of the stool, which decreased again when the saline intake was reduced. Visscher, Fetcher, Carr, Gregor, Bushey and Barker (1944) have shown that absorption of sodium, chloride, and even water is not a simple process of diffusion, but may differ by 200-fold from rates calculated from concentrations of these substances ; and it is not impossible that an active

process of this kind should be impaired in severe sprue, or even in chronic starvation. Although diarrhoea is the main cause of salt deficiency in these patients, the salt intake is also concerned. Anorexia interferes with the intake of salt and salt-containing foods, and thirst is relieved by fluids which contain little or no salt. Observations suggest that adrenal insufficiency, suggested by Thaysen (1932) as a cause of hypotension in steatorrhoea, was not an important factor in these patients. No increase in the serum potassium was observed; and in patient No. 10, sodium was adequately retained by the kidneys. Moreover, Prunty and Macoun (1943) in their case of salt deficiency in idiopathic steatorrhoea found no biochemical evidence of adrenocortical deficiency. Spruе patients with hypotension do not respond clinically to therapy with desoxycorticosterone acetate (Leishman, 1945).

THERAPEUTIC IMPLICATIONS

When the likelihood of salt deficiency occurring in cases of sprue with profuse diarrhoea is appreciated, much can be done in the way of prophylaxis. The diets normally used in the treatment of sprue are of no more than average salt content, and they require to be supplemented by the liberal addition of salt in cooking and seasoning, in any patient who develops diarrhoea. When anorexia interferes with the intake of food, it becomes even more important to give salt as well as fluid. Skimmed milk, which forms a high proportion of the early sprue diet, contains less than 0·2 g. of salt per 100 cc. The addition of 0·3 g./100 cc. (11 g. per pint) is well tolerated. Orange or lemon juice fortified by 0·45 g. of salt per 100 cc. is suitable drink, and it was found that sprue patients take it well. A daily intake of 15 g. of salt should be aimed at in the sprue patient with diarrhoea in the tropics. The actual food in a sprue diet supplies only 5 g. of this, and the remaining 10 g. has to be added in seasoning, and in weak saline drinks.

In established salt deficiency, more intensive salt therapy by mouth has to be given. Although these patients do not usually complain of thirst, they take saline fluids well. The limit to the amount of saline fluid which can be given by mouth is set by increase of diarrhoea, and improvement on oral therapy may take some days. In only one patient of this series was it found necessary to give saline by vein. Even more important than replacement therapy is the necessity of cutting short the watery diarrhoea which is present in nearly all these patients. Although the stools have not shown the exudate of bacillary dysentery, sulphaguanidine has been found effective in four patients of this series whose diarrhoea did not respond to diet and rest in bed. Parenteral liver should also be given as part of the general treatment.

With treatment on the lines suggested, all the patients in this series made a good recovery from their acute state of circulatory insufficiency. The stool fats, as might be expected, were not restored to normal, although they became lower when diarrhoea was arrested. The patients were, however, brought from a state in which they seemed likely to succumb to one in which rountine therapy for sprue could be applied and take effect.

SUMMARY

Between 5 and 10 per cent. of patients with sprue acquired on military service have had a low blood-pressure, asthenia, and signs of peripheral circulatory failure. Ten such patients were found on investigation to have a low serum sodium and serum chloride, and in some cases a plasma volume which was low in relation to their actual body-weight. Of these abnormalities the low serum sodium was the most pronounced.

A balance experiment on a typical patient showed abnormal loss of sodium, and to a less extent of chloride, in the faeces ; in the urine, sodium was rigidly conserved, while chloride was excreted, though in amounts less than normal. When the patient was put on a high intake of salt, sodium and chloride were retained, and the serum sodium and chloride were retained, and both rose to normal levels ; the blood pressure rose, and clinical signs of dehydration disappeared, although the abnormal loss of fat in the stools was not affected.

It is considered that such patients show the clinical and biochemical pattern of salt deficiency, modified by some degree of acidosis, owing to the preponderant loss of sodium over chloride in the stools. Loss of electrolyte in copious watery stools is thought to be the main cause of the salt deficiency, but diminished intake of salt in anorexic patients is also a factor. The results reported do not suggest adrenal insufficiency, for the serum potassium was not increased, and conservation of base by the kidneys was adequate. Treatment by increasing the salt intake to 15 g. per day corrects the dehydration in a few days, and intravenous saline had to be given in one patient only. If watery diarrhoea does not respond to diet and rest in bed, replacement salt therapy should be supplemented by sulphaguanidine, which has been found to check this type of diarrhoea.

Case Report (Patient No. 10)—(Age 22 years. Tropical service 1 year)

Previous History : Since 1939, 'dyspepsia'—epigastric pain, heartburn, and occasional vomiting after fatty meals. A barium meal had been done and was normal. There was no previous history of diarrhoea, dysentery or malaria.

His present illness began in May 1946, when he was in Eastern Bengal. The onset was sudden, with the passage of copious frothy watery stools. Loss of appetite and abdominal distension were present from the beginning, and he became very weak. Flatulence and abdominal discomfort were prominent symptoms from the onset, whereas tongue signs did not appear until three months after the diarrhoea began. He was evacuated to base, and admitted to hospital on 20 September 1945.

Condition on Admission : The patient was severely ill, and showed clinical signs of dehydration, dry wrinkled skin, coated tongue, and diminished intraocular tension. The pulse was weak and dicrotic, and the superficial veins were noticeably collapsed. Blood pressure was 100/70 and fell to 90/56 when the man sat up ; the pulse rate was 90 rising to 96 on sitting. The man's appetite was poor, but he took fluids well. The tongue was painful and reddened at the tip and sides, depapillated but not fissured. Abdominal distension was present, with flatulence ; the patient was passing 10 pale fluid copious stools daily.

The patient's weight was 87 lb., his normal weight being 154 lb. A blood count showed Hb. 12 g./100 cc. and RBC 3·0 million/cu. mm. A three-day specimen of faeces weighed 3·5 kg., the dry weight being 239 g. This contained 36 per cent. fat, the total output of fat in three days being 87 g. of which 82 g. were 'split'. No mucus or inflammatory exudate was found in the stools.

Progress under Treatment : The patient was put on a sprue diet containing 118 g. protein, 45 g. fat and 159 g. carbohydrate per day, the total calorie intake being 1,513 per day. This diet contained less than 5 g. of salt per day, and it was supplemented during the first 3 days of observation by 5 g. of salt to bring the salt content nearer a normal level. Even on this diet, comparatively restricted in salt, the serum sodium rose, and concurrently the patient's circulatory state improved so that by 21 September, four days after admission his pulse rate had fallen to 72 per minute and his blood pressure was 104/70 lying, but rose to 110/75 on sitting up. After three days on a 'normal salt' diet, the patient was put on a 'high' diet, with 25 g. of salt per day. This had to be reduced after three days to 15 g., for the patient's appetite became capricious, and he passed increased amounts of watery stools. Specific sprue therapy with parenteral liver extract was begun, and sulphaguanidine was given in a total dose of 70 g. in four days ; the stools became formed within three days, the wet weight being 300 g./day. The general condition improved rapidly and a month after the start of treatment the patient's weight had risen from 87 to 128 lb. His blood pressure was normal, tongue signs had disappeared, and he felt well, although his stools remained bulky and he was passing 96 g. of fat in three days.

DISCUSSION ON ABSORPTION

Not only is sprue a disease 'of unknown aetiology' but even the mechanism or functional pathology of the steatorrhoea has been the subject of conjecture rather than of experiment. In this investigation the main object was to gather as reliable information as possible about the natural history of the fat absorption defect in early sprue, for the only test of theories lies not in their logical consistency but in their correspondence with observed facts. It is a matter of general agreement that the failure to assimilate fats in sprue is not caused by faulty digestion of the fat, for the lipolytic activity of duodenal contents is normal in sprue. It is fairly certain, too, that the steatorrhoea in sprue does not represent an excessive secretion of fat by the intestine, for on a fat-free diet the steatorrhoea disappears (Wintrobe, 1942). For these reasons, it has come to be accepted that the functional lesion in sprue lies in the failure of transfer of fat or of fatty acids from the lumen of the bowel to the blood or lymph vessels ; but widely different views have been expressed as to the mechanism of this failure in absorption.

MECHANICAL THEORIES OF SPRUE

Bennett and Hardwick (1940) have suggested that sprue forms one example of 'chronic jejuno-ileal insufficiency', and compare it with surgical removal of part of the small intestine. Hurst (1941) postulated a loss of the pumping action of the villi. Stannus (1942) criticises these mechanical theories of the absorption defect in sprue at some length, and the members of the sprue research team are in agreement with his criticism. In addition to the evidence which he brings forward against such explanations, they point out that a non-specific 'insufficiency' of the small intestine would affect substances other than fat ; yet they observed that in the early stages of sprue there is gross steatorrhoea but no evidence of impaired absorption of iron, amino-acids, nitrogen or chloride ; while the absorption of iodide, although it may be gastric rather than intestinal, is also normal. Moreover, the findings that percentage fat absorption remains the same when the fat content of the diet is moderately increased tells against the mechanical theories ; for if there were rigid mechanical defect in absorption, one would expect

that the added fat in the higher diet would be excreted quantitatively, thus lowering the percentage fat absorption. For these reasons, in addition to those brought forward by Stannus, it seems that the failure of fat absorption is not a ' mechanical ' but rather a ' biochemical ' one.

NORMAL FAT ABSORPTION

The difficulty of explaining the fat absorption defect in sprue is very much increased by the fact that the normal mechanism of fat absorption is still a matter of controversy. The general view is that all fats are split before absorption, the glycerol is then absorbed in watery solution, while the fatty acids are absorbed as fatty-acid-bile-salt complexes, as cholesterol esters, or as phospholipids. Frazer (1940) has suggested that a certain amount of fat may be absorbed without previous splitting, as a fine emulsion, and that this type of absorption is associated with an increase in the chylomicrons, the small fatty particles seen in the blood on dark-ground illumination. This absorbed neutral fat gains access to the blood-stream by way of the intestinal lymphatics and thoracic duct. In addition to neutral fat, there is also absorption of split fat, and this is by way of the intestinal blood vessels into the portal circulation, so that absorbed split fat has to pass through the liver before reaching the systemic circulation. Frazer brings forward a considerable body of experimental evidence to show that absorption of neutral fat is a possibility ; but the proportion of fat absorbed as ' neutral ' and as ' split ' fat has not been determined. If one accepts Frazer's identification of chylomicrons with absorbed neutral fat, an approximate calculation of the amount of fat absorbed in this way can be made ; for figures given by Elkes, Frazer and Stewart (1939) suggest that an increase in chylomicrons of 100 per field corresponds in a general way to a fatty acid increase of 20 mg./100 cc. This relationship can only be an approximate one, in view of the errors inherent in counting chylomicrons, and the large variation in the size of the particles. It is, however, in agreement with the amount of milk fat which must be added to clear serum to produce an opacity similar to that after the fatty meal ; and the average increase in neutral fat and fatty acid in the 11 normal subjects was 40 mg./100 cc., the average chylomicron rise being about 150.

The total amount of fat present in the chylomicrons found in the plasma after a 20 g. fat meal can be put at somewhere between 0·5 g., not a high proportion of the total fat known is to be absorbed, which is 90 per cent. or more of the amount given, in normal people. Moreover, in a number of sprue patients under liver treatment, flat chylomicron curves became normal, yet there was no corresponding measurable change in percentage fat absorption ; which implies that the amount of dietary fat involved in producing a normal chylomicron count was not large enough to be detected by fat balance work. On the other hand, the fat attributable to chylomicrons does represent a high proportion of the total blood fat increment. These conflicting observations can only be reconciled if one assumes that particulate fat is more slowly removed from the blood-stream than fat absorbed in other ways ; so

that the relatively small amount of fat absorbed in chylomicron form persists longer in the blood-stream, while the end-products of split-fat absorption are rapidly transferred to the liver or depots. The presence of lipase in the bowel implies that soon after a fat meal both neutral and split fat will be available for absorption. Since Frazer has demonstrated the possibility of neutral fat absorption, it seems likely that both processes will go on, but as Bloor (1943) points out, it is probable that most of the fat is absorbed in the split form and the amount of fat involved in chylomicron formation is not large enough to challenge this general conclusion.

QUANTITATIVE ASPECTS OF FAT ABSORPTION IN SPRUE

Absorption studies in early sprue show that the defect in fat absorption is a partial one, since two-thirds of the ingested fat does not appear in the faeces. Stannus (1942) has suggested that the absorption defect in sprue can be explained on the assumption that neutral fat is well absorbed, while the power to absorb split fat is lost, probably owing to defective phosphorylation. His hypothesis is an attractive one at first sight, for the partial nature of the defect in fat absorption, and the fact that nearly all the stool fat is split, appear to support it. When considered quantitatively, however, it cannot form the whole explanation, for the considerations given in the previous paragraph make it certain that neutral fat cannot account for two-thirds of the total fat absorption. Also, no conclusion can be drawn from the stool fat as to which form of fat has escaped absorption, for splitting of fat goes on actively in the stool in vitro, so that even the fresh stool is unlikely to give a true picture of the split fat and neutral fat ratio in the small intestine. This is especially so in sprue, where the high soap content of the stool increases the rate of splitting, probably by promoting emulsification.

These results do in general support one part of Stannus's hypothesis, that neutral fat is well absorbed. The chylomicron count is often normal in early sprue without diarrhoea, and the neutral fat increment in the fat curves in sprue is more nearly normal than either total fatty acid or phospholipid increment. More severe cases of sprue show a low chylomicron count, and in these, the percentage fat absorption may not be lower than in those with normal chylomicron counts, nor does their percentage fat absorption improve appreciably when the chylomicron count returns to normal with liver treatment. This group of observations strongly suggests that although neutral fat absorption, as judged by the chylomicron count, is normal in early sprue, it cannot account for any high proportion of the two-thirds of the total fat which is known to be absorbed in such cases. It follows from this that the failure in split fat absorption is far from complete, at any rate in early sprue. It may be pointed out in this connection that even a complete failure in phosphorylation would not lead to cessation of absorption of split fat, for some fatty acid is absorbed in the form of complexes with bile salts, and some in the form of cholesteryl esters. There is no evidence of any deficiency of bile output in sprue, for though the stools are pale, they contain normal amounts of bile pigment in the colourless reduced

form. There is no certain evidence as to how much part cholesteryl esters normally play in fatty acid absorption, although it is known that in some cases a fatty meal is followed by an increase in cholesteryl esters in the serum (Knudsen, 1917). The low values for cholesterol in the serum in sprue and the fall which occurs in serum cholesterol after a fatty meal in that disease, suggest that in sprue less fatty acid may be absorbed in this way than in normal people. It is believed that the time has not yet come for a final evaluation of the relative importance of the absorption defects in the different fatty fractions in sprue, as it is still not known what proportions of ingested neutral fat are absorbed as neutral fat, as phospholipid, as cholesteryl ester and as bile-salt-fatty-acid complexes in normal subjects.

PHOSPHORYLATION

The work of Sinclair and later of Verzar has established the importance of phosphorylation as an intermediate stage in the absorption of fatty acid ; though here again, all that is certain is that the process occurs and it is not known what proportion of fatty acid is absorbed with phospholipid as an intermediate stage. The evidence for phosphorylation is mainly based on analyses of the fats in intestinal mucosa, and on absorption studies with isolated intestinal loops; neither method can be applied to the patient with sprue. It is hardly possible to obtain direct evidence of a failure of phosphorylation in the disease. The results of present study give no direct evidence of phosphorylation defect, but sprue patients showed a distinctly smaller increase in serum phospholipid after the fat meal than did normal patients. Although serum phospholipid is not directly derived from the intestine (Reinhardt *et al.*, 1944) the increase in serum phospholipid after a meal may well bear some relation to the amount of fatty acid absorbed directly into the portal system, carried to the liver, and there phosphorylated. Later in this chapter, evidence is given to show that yeast extract in large doses exerts a favourable effect on fat absorption in sprue ; and it is known that yeast extract corrects the phosphorylation defect found in adrenalectomised rats poisoned by phosphorus (Bloor, 1943).

ABSORPTION OF NON-FATTY SUBSTANCES

It has already been shown that absorption of neutral fat, as judged by the chylomicron count, may be normal in early cases of sprue, even with considerable steatorrhoea ; and this shows an impairment in other cases, particularly in those with diarrhoea, but also in some patients with formed stools. It seemed possible that an absorption defect, originally limited to fatty acid and possibly glucose, might later become generalised. To test this possibility, the absorption of several non-fatty substances has been examined. It was found that iron, nitrogen, amino-acids, chloride and iodide were well absorbed at a time when fat absorption, as judged by fat balance, was impaired. In cases of sprue in clinical relapse, however, it was found that iron and nitrogen

absorption might be defective ; in one patient the serum iron curve returned to normal levels with liver treatment. In patients with diarrhoea, secondary absorption defects are to be expected, and it was found that quite large amounts of sodium and chloride might be lost in the faeces ; adding salt to the diet increased the faecal sodium and chloride. Glucose occupies rather a special position, owing to the possibility of phosphorylation playing a part in its absorption. It was found that glucose tolerance curves might be normal in the presence of definite steatorrhoea ; but flat curves also were found in patients with only minor degrees of steatorrhoea, and with no other evidence of secondary absorption defects. It is doubtful how efficient blood sugar curves are in detecting minor degrees of a malabsorption of glucose, whereas the fat balance technique is capable of detecting quite small changes in fat absorption. So it is quite possible that glucose absorption is specifically impaired in sprue, although our methods of detecting it are not sensitive enough to demonstrate its presence in every patient with steatorrhoea.

Apart from data on the absorption of specific substances, some information of general absorption in sprue as opposed to fat absorption may be gained from the amount of NFDR in the stools. This method has the limitation that a large part of the dry stool residue is bacterial, but it is capable of showing gross changes in general absorption. The figures already given show that in many patients there is a decrease in the NFDR with improvement in fat absorption, and this may be due partly to an improvement in general absorption. In other patients, who show no change or even an increase in the NFDR, there may never have been any serious interference with general absorption.

DIARRHOEA IN RELATION TO ABSORPTION

Many patients with sprue have attacks of diarrhoea in which bulky formed stools are replaced by copious fluid motions. Such patients are very likely to become salt-deficient, and they excrete a large proportion of ingested fat during the diarrhoeic phase than either before or after it. Other absorption tests, such as the chylomicron count and the blood-sugar curve, also give evidence of impaired absorption in diarrhoea, over and above what is observed in the same patient when his stools are formed. Clinically these diarrhoeic attacks can be regarded either as complications or as integral parts of the sprue syndrome. Biochemically, they represent a phase in which the general absorption defect is especially pronounced. In a tropical country, such episodes of diarrhoea are sometimes found to be associated with the presence of dysentery bacilli and exudate in the stools. In other patients, although the stools contain no exudate, sulphaguanidine in full doses is followed by the passage of formed stools. In the belief that these diarrhoeic attacks may in some cases represent the results of intercurrent infection, or of lowered intestinal resistance to potential pathogens in the normal flora, findings obtained during diarrhoea have been excluded from this discussion of absorption in sprue.

SUMMARY OF DISCUSSION ON ABSORPTION

The steatorrhoea which is the salient feature of sprue is not caused by faulty digestion of fat, or by intestinal secretion of fat in abnormal amounts. There are four modes of fat absorption known to occur in normal people—absorption of unsplit fat, and absorption of fatty acids as phospholipid, as cholesteryl esters and as complexes with bile salts. The relative importance of these mechanisms in normal people is not certain. In early mild cases of sprue, neutral fat absorption is not demonstrably impaired and there is no deficiency of bile salts. There is some evidence that absorption of fatty acid as phospholipid and as cholesteryl esters is impaired. The absorption defect in early cases involves about one-third of the fat in the diet, and there may also be some impairment of glucose absorption, as judged by flat blood sugar curves after a glucose meal. Defective phosphorylation of fatty acid and of glucose is a likely mechanism of their defective absorption, but final proof of this is lacking.

In more severe cases of sprue, secondary absorption defects of substances such as neutral fat, iron, and nitrogen are added. These secondary absorption defects may occur in patients with formed stools. In patients with diarrhoea, secondary absorption defects are always present, and there is also a further diminution in the absorption of fatty acid and glucose. Patients with diarrhoea become dehydrated, and this may be the cause of death in patients with early sprue.

CLINICAL RESULTS

The treatment of sprue has long been based on the control of diet and the administration of liver (Manson-Bahr, 1943). Many different types of diet have been tried and success has been claimed for all, but since liver thearpy was shown to be an effective method of treatment by Castle, Rhoads, Lawson and Payne (1935) severe dietary restriction has been found unnecessary in most cases and diets have been planned on the principle of a high protein and low fat content (Fairley 1934). Here an attempt is made to assess the value of treatment based on such a diet, with and without the addition of drugs containing vitamins of the B group. The effect of therapy was carefully followed in 62 of the 80 patients of series B. As has been shown earlier, many of the patients in this series did not conform to the classical picture of tropical sprue, in that they were not severely ill, with only slight steatorrhoea and little anaemia. The following means of treatment were studied.

(1) Diet.
(2) Parenteral liver preparations.
(3) Nicotinic acid, riboflavin.
(4) Yeast extract

CRITERIA OF PROGRESS

During treatment, a marked clinical improvement in these patients did not always coincide with a demonstrable improvement in intestinal

absorption, as measured by fat balance experiments. Therefore, in assessing treatment it is necessary to consider separately any general improvement in the patient's condition and any change in intestinal absorption. The effect of various drugs on fat absorption are reported separately at the end of this chapter and the result will be mentioned here only in so far as they are relevant to the question of therapy. Satisfactory clinical progress was marked by weight gain and return of appetite. In those patients who had watery diarrhoea, such improvement only took place with the cessation of diarrhoea.

As described earlier, tongue signs and distension often appeared in patients who were otherwise improving, and these two signs were not considered to be unfavourable. Complete remission was indicated by :—

(i) Weight within 10 lbs. of normal.

(ii) Stools normal in number, colour and fat content.

(iii) Absence of distension and tongue signs.

(iv) No relapse on ordinary diet.

DIET

The composition of the diets used is shown in Table LII. Diets 3, 4 and 5 are based on those designed by Napier. Investigation diets 1 and 2 were similar to the Napier 4 and 5 diets respectively, but as yeast extract and liver were excluded, the vitamin content was lower. Except in patients who were the subjects of balance experiments the diets were only adhered to approximately.

TABLE LII

Values of the diets used in the treatment and investigation of sprue.

Diet	Calories	Carbohy-drate in g.	Protein in g.	Fat in g.	Vitamin A in IU	Thiamine in mg.	Riboflavin in mg.	Nicotinic acid in mg.	Ascorbic acid in mg.	Remarks
Investigation 1	2,037	215	139	69	1,600	1·1	3·1	10·1*	28	Investigation diets for therapeutic trials.
Investigation 2	2,620	290	149	96	3,200	1·3	3·2	11·1	50	
3	1,513	159	118	45	14,700	1·0	5·1	19·1	31	Diet used in the routine treatment of sprue.
4	2,109	233	139	69	16,200	1·3	6·2	27·2	31	
5	2,692	308	149	96	17,800	1·5	6·3	27·2	43	

*In some cases meat in the diet was replaced by fish; the content of nicotinic acid was then 4·9 mg.

Of the 62 cases, 10 were severe enough to require immediate liver therapy, 15 made slow progress and were later given liver therapy, 14 were improving, but still had symptoms when evacuated to the United Kingdom. It is likely that in many patients of this last group complete remission would have occurred during a longer period of observation. The remaining 23 cases were discharged in complete remission and apparently cured, so that at least one-third of the cases showed complete remission in the course of two to three months on dietary therapy alone. It is not possible to decide whether rest, regular meals, or the actual diet used was responsible for the improvement. As the therapy of sprue generally included parenteral liver or some analogous drug in order to obtain the most rapid and consistent results, it is more important to decide the relative importance of dietary control than to determine whether the improvement noted in the 23 cases quoted above was spontaneous or the result of dietary control. In the controlled diets used the following factors may be discussed.

(i) Calorie value.

(ii) Fat, carbohydrate and protein content.

(iii) Vitamin content.

Calorie Value : The calorie value of the diets ranged from 1,500 to 2,600 calories. Patients with complete anorexia and copious watery diarrhoea were not even able to take the full 1,500 calorie diet, but after beginning liver therapy all patients were able to take either the 2,000 or the 2,600 calorie diet, and most of them gained weight on the higher diet at a rate of up to 4 lbs. a week. The calorie value of the diet which such patients can take is to some extent limited by their tolerance for fat and carbohydrate, even when their appetite is good, so that it is often unsafe to allow a patient to eat as much as he wants, since a return of intestinal symptoms may be precipitated.

Fat Content : For any given patient the fat content of the diet determines the degree of steatorrhoea, as has been shown earlier in this chapter ; with a minimal fat intake the steatorrhoea disappears, and within the limits of a moderate fat intake of 65 g. to 96 g. per day the proportion of fat absorbed is fairly constant, varying from 50 to 90 per cent. in different cases, so that, other things being equal, more fat is absorbed when more is given. From the therapeutic point of view this is important since apart from its high calorie value dietary fat contains the fat soluble vitamins. On the other hand, it is also true that the more fat there is in the diet, the more there is in the faeces, and while theoretically a high intake may be desirable in a patient who only absorbs a proportion of his intake, the amount that can be given is limited by the degree of steatorrhoea that can be tolerated. Steatorrhoea produces symptoms in two ways. Firstly, the amount of soaps in the bowel depends directly on the amount of fat, and, unless calcium is added to the diet, these soaps consist partly of sodium and potassium soaps which are soluble and irritant and produce diarrhoea. The diarrhoea may be quite severe and lead to a rapid deterioration in the patient's general condition. Secondly the presence of much fat in the bowel causes distension.

TABLE LIII

Dietary supplements used. (Sprue patients not on parenteral therapy).

Diet	Complete remission	Incomplete remission
Napier:		
Without supplement	0	0
With cooked liver, 4 oz. daily	12	5
With yeast and liver	10	8
Investigation:		
Without supplement	1	0
With yeast extract	0	1
Total	23	14

The 37 cases shown in this table represent the number of patients out of a total of 62, who did not require parenteral liver therapy.

Bulk exacerbates the symptom of distension. In practice it was found that the patients did not tolerate a faecal excretion of fat greater than 25 g. to 30 g. per day.

Carbohydrate Content : It is well known that the absorption of carbohydrate is defective in sprue though this defect can be demonstrated only by blood curves and not by balance studies, since unabsorbed glucose derived from the digestion of dietary carbohydrate is to a great extent fermented by the bacteria in the colon. Thus, it is not known whether fat and glucose absorption defects parallel each other in a given case. Unabsorbed glucose, like unabsorbed fat which has been changed into soluble soaps, is not inert and may cause flatulence and distension as a result of fermentation ; it is not known whether the breakdown products of carbohydrate fermentation may cause diarrhoea, but this is a possibility. Thus, the amount of carbohydrate as well as the amount of fat which may be given to sprue patients is limited by the possible appearance of symptoms of relapse.

It has been suggested (Stannus, 1942 ; Maegraith, Adams, Havard, King and Millet, 1945) that fructose is well absorbed in sprue, but evidence to the contrary has been obtained. The virtues claimed for strawberries and bananas in the treatment of sprue would have to be explained in some other way than by their high fructose content.

Protein Content: Protein is the only class of food which is well absorbed in sprue ; even in cases with diarrhoea the increased loss of nitrogen in the faeces is no more than can be accounted for by the increase in intestinal secretions. Hence, the amount of protein which can be given to patients with sprue is limited only by their appetite. As far as possible in these cases the protein intake was maintained at 140 g. to 150 g. per day. The possible virtues of the high protein diet are three-fold. Firstly protein supplies a source of energy in an absorbable form.

Secondly protein is required for the replenishment of the body stores of protein which are depleted in many patients with sprue, as evidenced by the generalised muscular wasting and the low plasma protein levels. Thirdly, the high protein diet may be a source of a food factor deficient in sprue and shown below to be present in liver and yeast extract. That protein is well absorbed and utilised in sprue patients in remission is shown by the positive nitrogen balances found in such patients (as shown earlier in this chapter).

Vitamin Content : The vitamin content of the diets other than the two 'investigation' diets was greatly modified by the inclusion of cooked liver (4 oz. daily), yeast extract in the form of vegemite (2 teaspoonsful daily), or yeast food (1 oz. daily). In 36 out of the 37 patients who improved without parenteral liver therapy, these supplements were included in the diet, as shown in Table LIII. No adequately controlled data was obtained on the clinical effect of yeast extract (vegemite) by mouth. This substance was given either to the mildest cases who did not require parenteral liver or to severe cases after usually prolonged therapy with parenteral liver. It is shown later in this chapter that the yeast extract when given by mouth in large doses (20 g. daily) rapidly improves fat absorption in some patients and for this reason alone it may be considered a useful adjunct to therapy. On the other hand it is unpleasant to take in such large quantities and in some patients produces flatulence and heartburn.

RESULTS OF PARENTERAL THERAPY

Controlled observations on the effect of different forms of parenteral therapy in sprue were made on those patients who were also the subjects of balance experiments. In these patients the prescribed diets ('investigation' 1 and 2) were either rigidly adhered to or else any deviation from the set diet were recorded from day to day. The diets contained no liver or yeast.

EFFECT OF NICOTINIC ACID AND RIBOFLAVIN

Perhaps because the tongue lesions in sprue sometimes resemble those of pellagra or sometimes those reported in riboflavin deficiency, nicotinic acid and riboflavin have been used and recommended in the treatment of sprue, though there appear to be no controlled observations on the effects of these substances in sprue. In the course of experiments on the effects of these substances on fat absorption, observations were made on their clinical effect. Very few of the cases had well-marked tongue lesions, and the only common lesion was a slight reddening at the tip and sides accompanied by soreness. Six patients received nicotinic acid (50 mg. t.d.s.) and riboflavin (5 mg. daily) parenterally. All but one were more than 20 lbs. under weight. In three the appetite was poor and two complained of sore tongue at the time of beginning the treatment. All had steatorrhoea but none had watery diarrhoea. At the end of a twelve day trial of this combination of drugs there was no significant change

in any of the patients as regards weight, appetite and tongue symptoms. The steatorrhoea was not improved and possibly made worse. Two more patients who were given nicotinic acid similarly failed to respond.

EFFECT OF PARENTERAL LIVER

Parenteral liver therapy was ultimately given to all those patients who did not respond satisfactorily to diet and rest alone. The result of such treatment, using 'TCF' (an Indian preparation) or 'hepastab' (Boots) are summarised in Table LIV. These preparations were for a long time the only ones available.

Seventeen cases represented in Table LIV were all on a known diet, and received four daily doses of 10 cc. of liver extract followed by either 2 cc. or 4 cc. daily. In some this treatment was preceded by treatment with nicotinic acid and riboflavin, shown above to be ineffective. In such cases the vitamin therapy was continued during the trial of liver. Other deviations from the standard treatment are shown in the table. The effect of treatment was assessed by changes in weight, appetite, tongue symptoms and diarrhoea at the end of a twelve-day period. The appetite was improved in all six patients who had been complaining of poor appetite, and soreness of the tongue disappeared in four patients who had been complaining of this symptom. Five of the patients had watery diarrhoea when on liver therapy alone. These results may be compared with the known effects of crude liver extracts (Castle, Rhoads Lawson and Payne, 1935; Rodriguez-Molina, 1943) which in sprue cases improve the appetite, regress the tongue lesions and frequently arrest the diarrhoea. These effects have been attributed to the replacement of an unknown factor deficient in sprue patients. It is interesting to note that these effects were to some extent reproduced in the patients under investigation with relatively purified liver extracts. The weight changes are analysed separately in Table LV, in which patients 6 and 17 are not included since their weight was normal at the beginning of the trial. The remaining 15 patients are grouped according to their dietary intake and according to whether or not they had diarrhoea at the beginning of the trial.

The patients without diarrhoea responded roughly according to their calorie intake, in that there was no significant gain in weight in the three patients whose calorie intake was less than 2,100 calories per day, while the seven patients whose intake was over 2,100 calories showed an average weight gain of 4 lbs. during the first 12 days of liver treatment. In the patients with diarrhoea the weight response was variable. There was no response in those patients in whom the diarrhoea was not arrested (cases 4 and 5); with arrest of diarrhoea case No. 18, on a 2,400 calories intake, gained 6 lbs. in weight, case No. 25 gained only 1 lb. but was on a 1,600 calories diet, case No. 11 gained 9 lbs. on a similar intake, but a lot of this gain was due to water retention, subsequent to the arrest of the diarrhoea.

TABLE LIV

Effect of 12-days parenteral liver therapy in sprue.

Case Number.	Liver preparation used.	Maintenance doses.	Average calorie intake during 12 days before beginning liver.	Average calorie intake during 12 days on liver.	Normal weight.	Weight before beginning liver.	Weight after 12 days liver.	Appetite Before	Appetite After	Tongue Before	Tongue After	Diarrhoea Before	Diarrhoea After
2	TCF	2 cc.	2,080	2,040	164	134	136	Poor	Good	Sore	N	— Absent —	
4	,,	,,	2,080	2,060	150	130	130	Good	Excessive	— N —		— Present —	
5	,,	,,	2,050	2,360	123	115	112	— Good —		— N —		— Present —	
6	,,	,,	2,670	2,620	140	136	136	— Good —		— N —		— Absent —	
8	,,	,,	2,260	2,675	139	122	126	— Good —		Sore	N	— Absent —	
10	,,	,,	2,460	2,280	152	126	130	— Good —		— N —		— Absent —	
11	,,	4 cc.	1,380	1,600	155	88	97	Poor	Good	— N —		Present	Absent
12	,,	,,	2,220	2,220	148	129	132	— Good —		— N —		— Absent —	
14	,,	,,	1,780	2,000	134	112	114	— Good —		— N —		— Absent —	
15	,,	,,	2,320	2,410	144	126	131	— Good —		— N —		— Absent —	
17	,,	,,	2,380	2,373	94	110	109	-- Good —		— N —		— Absent —	
18	,,	,,	2,170	2,420	158	114	120	Poor	Good	Sore	N	Present	Absent
19	,,	,,	...	1,585	140	84	85	Poor	Good	Sore	N	— Absent —	
20	,,	,,	2,360	2,550	146	130	136	— Good —		— N —		— Absent —	
23	Hepastab	,,	2,370	2,480	130	114	116	Poor	Good	— N —		— Absent —	
24	,,	,,	2,490	2,510	144	136	140	— Good —		— N —		— Absent —	
25	,,	,,	1,970	1,600	142	105	106	Poor	Good	— N —		Present	Absent (Sulphaguanidine given)

Note: 1. All patients received 10 cc. of liver daily for four days at the beginning of treatment, followed by the daily maintenance dose shown.

2. N=Normal.

TABLE LV

Weight changes (in lbs.) during 12-days on parenteral liver therapy, grouped according to the calorie intake and according to the presence or absence of diarrhoea at the beginning of treatment.

Cases	Calorie intake: Below 1,650	1,650-2,100	Over 2,100
Cases without diarrhoea ...	(19) : +1	(2) : +2 (14) : +2	(8) : +4 (10) : +4 (12) : +3 (15) : +5 (20) : +6 (23) : +2 (24) : +4
Cases with diarrhoea ...	(11) : +9 (25) : +1	(4) : 0	(5) : —3 (18) : +6

Note : The numbers in parentheses denote individual patients in the series.

In spite of the weight gain shown by these patients when on an adequate diet, liver therapy (using the semipurified extracts) could not be shown to improve fat absorption in a twelve-day period, though it did so over longer periods of treatment.

Details of the clinical changes with parenteral liver therapy are given in summary form :—

(i) *Mental :* Subjective improvement (1-2 days).

(ii) *Skin :* Change from pallor to pink (2-3 days) ; later scaling may be marked (6-12 days).

(iii) *Alimentary Tract :*

(a) Appetite improves ; vomiting stops (4-6 days).

(b) Tongue ; slight if any glossitis, etc. (4-6 days).

(c) Diarrhoea stops (6 days) ; stools formed, bulky, yellow.

(d) Abdominal distension increases (1 week onwards), with cessation of diarrhoea.

(e) Gastric juice ; restoration of HCl in two histamine-fast achlorhydrics (1-2 months).

(f) Barium meal ; in one instance change from gross bolus formation to normal appearance of mucosal pattern occurred in 4 weeks.

(iv) Weight gain begins during the first week and persists.

(v) Weakness diminishes (1-2 weeks).

(vi) Blood-pressure increases from hypotension (1-5 weeks).

(vii) Blood : macrocytic anaemia responded slowly using TCF.

TREATMENT OF SPECIAL SYMPTOMS

Diarrhoea : The commonest symptom requiring special treatment in sprue is diarrhoea, when it does not respond to parenteral liver therapy. Diarrhoea is often simply due to dietary excess and is relieved when the carbohydrate and fat content of the diet is reduced, but the very severe cases often have a copious watery diarrhoea though taking minimal amounts of food. These cases may become severely dehydrated owing to salt deficiency. It was found that in these cases the diarrhoea may be arrested by combining a course of sulphaguanidine with parenteral liver therapy. Sulphaguanidine also frequently controls diarrhoea in sprue without added liver therapy, but the effect is transient and the diarrhoea often returns when the drug is discontinued. The beneficial effect of sulphaguanidine in sprue is surprising since no pathogenic micro-organisms can as a rule be isolated in these cases, and it must be assumed that the drug acts by inhibiting the growth of bacteria which are normally not pathogenic but which assume a pathogenic role in the sprue patient. It is reasonable to suppose that the atrophic intestine of the sprue patient might show a diminished resistance to bacterial irritants. This would explain why the diarrhoea may be controlled by sulphaguanidine but relapses unless parenteral liver therapy is given at the same time, since sulphaguanidine would not affect the mucosal atrophy.

Salt Deficiency : As shown earlier in this chapter, a deficiency of salt is the cause of the dehydration with hypotension which may be found in the worst cases of sprue. This is partly due to the excessive loss of electrolytes in the copious watery stools and partly to the diminished intake of salt associated with a small fluid intake. In these cases efforts to control the diarrhoea must be combined with treatment of the water and salt deficiency. Patients may be made to take from 10 g. to 15 g. extra sodium chloride daily, and for this lemon squash was found to be a good vehicle.

Anaemia : As shown earlier in this chapter, few of the patients were seriously anaemic. In those whose response to TCF was not satisfactory and when the RBC count was below 2 millions per c.mm. a transfusion of whole blood was given. In three patients to whom this treatment was given there was rapid improvement in the patients' condition, but one of the patients required more than one transfusion. The impression was gained that some factor other than the red cells plasma components exerts a 'trigger' effect, whereby red cell production is markedly increased and other tissues, e.g. the alimentary tract are beneficially affected.

GENERAL MANAGEMENT OF THE SPRUE PATIENT

From the observations and conclusions outlined above certain principles in the treatment of sprue may be given. The indicators for the various forms of treatment are shown in tabular form in Table LVI.

Table LVI

Recommendations for the treatment of the various types of acute sprue.

Type of case	High protein diet, Napier 1-5+oral liver (cooked)	Parenteral liver 10 cc. daily for 4 days; then 4 cc. daily	Sulphaguanidine 7g. stat, then 3, 5 g. four hourly total 70 g.	Sodium chloride 10 g. daily	Blood transfusion
Acute sprue mild:					
(a) In remission	+	—	—	—	—
(b) Static or in relapse	+	+	±	+	+
Acute sprue severe	+	+	+	+	±
Acute sprue with severe anaemia	+	+	+	—	+

+Indicated. ±Indicated in certain cases. —Not indicated.

Except in the very mild cases, and certainly in any patient with loss of weight, hospital treatment is indicated, because rest is important in this disease and, in spite of the benefits of parenteral liver therapy, dietary control is essential for efficient treatment. The diets should have a low residue and the food be given regularly. For the patient with a capricious appetite it is important that the food should be well prepared. The diets designed by Napier have proved very useful. In the severe cases in relapse diet 3, and in the milder cases diets 4 and 5

have been used. The patient should take the full diet possible without producing symptoms of relapse, of which the most important is diarrhoea. Weight gain is not assured until he is able to take diet 5.

Parenteral liver therapy is in many cases essential to the success of dietary therapy and hastens recovery in all cases. In many patients an increase in dietary intake would be impossible without parenteral liver. Large daily doses must be used, and the extract should be crude, though good results are obtained with semi-purified extracts. Occasionally parenteral liver and dietary control fail to arrest the watery diarrhoea and in these cases sulphaguanidine has proved invaluable. These cases may be complicated by dehydration due to salt deficiency, and this condition calls for urgent treatment. In cases with severe anaemia a transfusion may be required to initiate recovery.

Fat absorption improves slowly on this regime, using semi-purified liver extracts. In many cases yeast extract by mouth accelerates the improvement in absorption and is a useful adjunct to therapy. It has to be given in rather large dose which some patients find unpleasant to take.

After eight to twelve weeks on this regime most patients are apparently in complete remission but no data on the relapse rate are available.

EFFECT OF THERAPY ON FAT ABSORPTION

Using the fat balance technique described earlier in this chapter, a study was made of the effect of various substances on fat absorption in sprue. The 23 patients selected for this investigation had all failed to improve on dietary therapy alone. Because of the variability of fat output over short periods, conclusions are based on results grouped into twelve-day periods, except in a few cases specified in the tables. Interpretation of the results must take into account the possibility of spontaneous improvement. This consideration does not affect the interpretation of negative results of treatment. In the case of yeast extract, in which early results suggested a positive action on fat absorption, a double pre-period was used for the later cases, so that any spontaneous improvement which was going to occur might become apparent. Minor difficulties in interpretation arise from the occasional incidence of watery diarrhoea, the change in some patients from a 65 g. fat diet to a 96 g. fat diet, and the possibility that part of the faecal fat is a true excretion, and not unabsorbed food fat. Patients with watery diarrhoea were excluded from the series until the diarrhoea had been controlled by liver treatment or sulphaguanidine ; watery stools with solid particles cannot be fairly sampled, and diarrhoea itself affects fat absorption. With regard to dietary variation, it was found that change of diet from 69 g. to 96 g. of fat per day did not affect the percentage fat absorption enough to interfere with interpretation of fat balance results. It was also found that on a fat free diet, sprue patients excreted no more fat than normal subjects. The fat so excreted as opposed to unabsorbed fat represents only a small systematic error which does not affect significantly the comparison of successive periods.

Effect of Nicotinic Acid and Riboflavin : Table LVII gives the fat absorption figures in two patients treated with nicotinic acid 50 mg. t.d.s., and in four patients treated with nicotinic acid 50 mg. t.d.s. and riboflavin 5 mg. daily ; these drugs were given intramuscularly.

TABLE LVII

Effect of nicotinic acid and riboflavin on fat absorption.

Patient Number	Period 1		Period 2		Difference in percentage of fat absorption between the periods
	Duration (days)	Percentage fat absorption	Duration (days)	Percentage fat absorption	
6	12	79·5	9	74·8	−4·7
9	12	79·8	8	70·4	−9·4
12	12	89·4	12	79·8	−9·6
14	12	77·2	12	75·2	−2·0
15	12	80·0	12	73·6	−6·4
17	12	79·2	12	82·3	+3·1

Note : Period 1 in all cases was without treatment. In period 2, all patients were given 50 mg. nicotinic acid t.d.s. in addition, patients 12, 14, 15 and 17 were given 5 mg. riboflavin daily.

In none of the six patients was there any significant change in fat absorption ; taking the series as a whole, there was a small drop in fat absorption in five of the six patients. The figures for the four patients who had both nicotinic acid and riboflavin were analysed together, and the probability of the fall being due to chance is 0·1. There was, therefore, no evidence that nicotinic acid and riboflavin improved fat absorption, and it was suggestive that fat absorption actually deteriorated to some extent. Since the two cases treated with nicotinic acid alone showed also a deterioration of the same order, it seems likely that in the combination of the two drugs, it was the nicotinic acid which was responsible for the deterioration. As shown earlier in this chapter there was no clinical improvement with nicotinic acid or riboflavin. These results conflict with the claims of Manson-Bahr (1941). As Stannus (1942) points out, most of Manson-Bahr's cases were having liver treatment at the same time as nicotinic acid, and this may have accounted for the improvement which he observed. While it is possible that nicotinic acid or riboflavin may have a favourable effect on the tongue lesions in cases with well established secondary deficiencies of these vitamins, the results suggest that the fundamental anomaly in sprue, the failure of fat absorption, is not influenced by such therapy. Intensive therapy with single vitamins may even be harmful, by accentuating a multiple vitamin deficiency 'vitamin imbalance' (Morgan, 1941).

Effect of Liver Extract : The value of liver extract in the treatment of sprue is well established and as far as clinical improvement is

concerned this was confirmed in these cases. Barker and Rhoads (1937) found that large doses of crude liver extract given by injection improved the absorption of fat in sprue as judged by the serum lipid curve after a fatty meal. Serum lipid curves are open to some criticism, in that the normal range is wide, and also they can measure only the rate of fat absorption, and not the total amount absorbed. The effect of liver extracts on fat absorption was observed by the balance technique in eight patients, four of whom were used for more than one trial, so that Table LVIII gives the results of twelve such experiments, each based on two successive twelve-day periods. Three liver extracts were used :—

(i) 'TCF' : An Indian preparation, the only one available for some months, described as containing 'most of the B complex substances present in the original liver'. It was semi-purified and though certainly not so crude as the preparation used by Rodriguez-Molina (1943), each cc. of which was derived from only 5 g. of fresh liver, it was found to be effective in the clinical treatment of sprue.

(ii) 'Hepastab' (Boots) : A moderately refined extract.

(iii) 'Hepatex-T' (Evans) : An extract containing the whole of the vitamin B complex naturally contained in liver, and also added thiamin and nicotinic acid. This preparation is designed for the treatment of tropical macrocytic anaemia.

The standard dosage used was 4 cc. daily for all preparations, and in all cases a loading dose of 40 cc. spread over 4 days was given at the beginning of liver treatment ; all doses were given intramuscularly. When Hepastab and Hepatex-T became available, they were used in order to see whether they would produce an improvement in fat absorption which was not found with the less well defined Indian preparation. With the exception of one trial of Hepatex-T (patient No. 20), there was no significant improvement in fat absorption, and the improvement of 12·2 per cent. in one case out of eight, though statistically significant, could easily have been spontaneous. Bassett *et al.* (1939) also failed to demonstrate any improvement in fat absorption with liver treatment of idiopathic steatorrhoea.

These negative results stand in very marked contrast to the striking clinical improvement shown by the patients on liver treatment. They gained weight rapidly, their appetite improved, tongue signs disappeared, and they felt much better. Liver extract also improved diarrhoea in many of those patients who had it ; for reasons already given, such patients have not been included in the fat absorption series. Moreover, it was found that patients who were kept on liver treatment for a month or more showed gradual improvement in their fat absorption (Table LIX).

The striking thing, however, is that with doses of liver extract sufficient to produce a rapid clinical improvement there is only a small and gradual effect on the fat absorption defect. This finding will be discussed later in relation to the results with yeast extract.

TABLE LVIII

Effect of liver extract on fat absorption in two successive 12 days periods.

Patient Number	Period I		Period II		Difference in percentage of fat absorption between the periods
	Treatment	Percentage fat absorption	Treatment	Percentage fat absorption	
2	None	50·7	TCF	47·0	—3·7
24	None	79·5	TCF	81·0	+1·5
23	None	88·5	H'stab.	82·0	—6·5
12	Nic., Rib.	79·8	Nic., Rib., TCF	83·0	+3·2
15	Nic., Rib.	73·6	Nic., Rib., TCF	78·0	+4·4
17	Nic., Rib.	82·8	Nic., Rib., TCF	83·4	+0·6
14	TCF	57·2	H'tex-T TCF	60·4	+3·2
15	TCF	78·0	H'tex-T TCF	79·6	+1·6
17	TCF	83·4	H'tex-T TCF	82·9	—0·5
20	TCF	69·9	H'tex-T TCF	82·1	+12·2
12	TCF	82·8	H'stab TCF	87·5	+4·7
24	TCF	81·0	H'stab TCF	81·8	+0·8

Note : Nic. is an abbreviation for nicotinic acid, Rib. for riboflavin, H'stab for Hepastab, and H'tex-T for Hepatex-T. The dosage of liver is given in the text ; patient No. 2 had 2 cc. of TCF daily instead of the standard 4 cc.

TABLE LIX

Effect of continued liver treatment (5-7 *weeks*) *of fat absorption.*

Patient Number	Period 1. (Pre-treatment) percentage fat absorption	Period 2. (after 5-7 weeks liver) percentage fat absorption
4	75	79
11	61	77
14	75	81
15	80	79
17	79	83
19	77	84
20	70	82
24	80	87
Means	74·6	81·5
Standard difference ...	±6·44	±3·21
Difference between means ...	6·9	
Standard error of difference ...	±2·44	

The difference between the means is statistically significant.

Yeast Extract : The preparation used was 'vegemite', which resembles marmite and is manufactured in Australia. It was given in a dose of 5 g. four times a day. The effect of treatment with yeast extract on fat absorption is shown in Table LX. In all cases, the patients who were given the yeast extract were also on either 4 cc. or 2 cc. of liver extract daily ; the reasons for this procedure were as follows :—

(i) It has already been shown that liver extract in the dosage used given over a period of less than a month does not improve fat absorption demonstrably, so that any observed improvement within this period can be ascribed to the added yeast extract.

(ii) As far as possible, severely ill patients were chosen for this study, to lessen the chances of spontaneous improvement. Such patients are liable to diarrhoea, with rapid deterioration in their general condition, and such relapses can be controlled or prevented by liver treatment.

(iii) Since no yeast extract suitable for parenteral injection was available, liver extract was given to insure that any favourable action of yeast extract should not be prevented by a secondary absorption defect, such as may occur in sprue and be amenable to liver therapy.

TABLE LX

Effect of yeast extract on fat absorption.

Patient Number	Duration of liver treatment before giving yeast extract (days)	First preliminary period			Second preliminary period			Yeast extract period		Difference in percentage of fat absorption between periods	
		Duration (days)	Treatment	Percentage fat absorption	Duration (days)	Treatment	Percentage fat absorption	Treatment	Percentage fat absorption	(2—1)	(3—2)
3	0	6	None	73·0	12	Nic.	68·8	Nic, Rib. Liver, Y.	83·1	—4·2	+14·3
6	0	12	None	79·5	12	Nic.	83·5	Nic, Rib. Liver, Y.	90·5	+4·0	+7·0
8	0	9	None	80·2	11	None	80·8	Nic, Rib. Liver, Y.	85·5	+0·6	+4·7
25	14	8	Liver	72·7	8	Liver	68·6	Liver, Y.	72·8	—4·1	+4·2
28	28	12	Liver	65·8	12	Liver	69·0	Liver, Y.	80·4	+3·2	+11·4
2	32	12	Liver	62·2	12	Liver	64·6	Liver, Y.	71·6	+2·4	+7·0
4	37	12	Liver	73·8	12	Liver	79·4	Liver, Y.	82·3	+5·6	+2·9
24	43	12	Liver	83·5	12	Liver	86·6	Liver, Y.	87·2	+3·1	+0·6
27	45	12	Liver	64·8	12	Liver	63·2	Liver, Y.	68·7	—1·6	+5·5
17	47	8	Liver	89·4	8	Liver	87·2	Liver, Y.	86·1	—2·2	—1·1
15	49	8	Liver	76·4	8	Liver	80·7	Liver, Y.	81·1	+4·3	+0·4
14	63	8	Liver	74·7	8	Liver	83·6	Liver, Y.	84·1	+8·9	+0·5

Note: Abbreviations as in Table LVIII. Y. = Yeast extract.
All the yeast extract periods were of 12 days.

Of the 12 patients represented in Table LX, the first six were put on yeast extract after 32 days or less on liver treatment, and their fat absorption in the first preliminary observation period ranged from 62

per cent. to 80 per cent. All the other six patients had liver for a longer period before yeast extract was started, and their initial level of fat absorption also tended to be higher, and in two cases was over 80 per cent. The patients were studied over 3 consecutive periods, each of 12 days where possible. They received yeast during the third period, but were otherwise on the same regime as in the two preceding control periods (except in respect of nicotinic acid in patient Nos. 3 and 6). From the first period to the second period there was often a slight but not significant improvement. From the second to the third period there was a marked improvement in fat absorption in the first six patients as shown in Table LX, which was significant for the six patients taken together. In the second group of six patients, who had been receiving liver therapy for a longer period, and whose fat absorption defect was in general less severe, yeast extract did not produce any detectable improvement except in one (patient No. 27) whose fat absorption had remained at a low level in spite of fairly prolonged liver treatment.

The results suggest that the yeast extract contains a factor which, in the doses used, improves fat absorption in many sprue patients. The results on the second group of six patients suggest that long-continued liver treatment may even with semi-purified extracts supply an adequate dose of factors similar to those in the yeast extract. While the yeast extract improved the fat absorption in most patients, it did not always bring it back to normal in these patients, suggesting that its action is a form of replacement therapy rather than curative. Bigger doses could not be tried as the extract is unpleasant to take in large quantities. No adequate observations were made to determine whether the yeast extract has the same beneficial effect on the tongue lesions and loss of weight in sprue as parenteral liver extract.

Finally, it has to be noted, as shown earlier in this chapter, that a large proportion of the patients in these series returned to normal without any form of parenteral therapy, on a diet of high protein content which usually included cooked liver and yeast extract. In these patients the steatorrhoea disappeared gradually or suddenly after a variable period in hospital and it was not possible to attribute this change to any known factor in the treatment.

DISCUSSION

The results of various forms of therapy in sprue may be interpreted in the light of later observations (Spies *et al.*, 1946a, b, c; Darby, Jones and Johnson, 1946) on the effect of folic acid in sprue. This substance, present in liver extracts, has a dramatic effect on some of the symptoms of sprue. In particular it is said to relieve diarrhoea and tongue lesions and to produce a rapid gain in weight and it cures the macrocytic anaemia of sprue. This suggests that it has an effect comparable to that of parenteral liver extract in this disease. The beneficial effect of liver extract may be due to its folic acid content and this is consistent with the statement (Lancet, 1946) that folic acid is not 'Haemopoietin', since highly purified extracts with maximal haemopoietic activity are recognised to be relatively ineffective in sprue. Like

parenteral liver extract, folic acid apparently does not improve the steatorrhoea of sprue. It is difficult to state with any certainty, whether all the effects of liver therapy are reproducible with administration of folic acid or the improvement noticed is a mere result of the arrest of diarrhoea. The patients gained weight rapidly with liver extract, while remaining on the same dietary intake.

As shown earlier in this chapter, patients in remission were in marked positive nitrogen balance, suggesting that they had at one time been in negative nitrogen balance, though absorption of nitrogen is generally not impaired in sprue. It would seem that patients with sprue are unable, in the ' relapse ' phase, to utilise properly absorbed nitrogen, and the weight gains recorded with liver therapy may be due to the correction of this metabolic abnormality by the provision of a deficient vitamin-like factor. There is experimental evidence that such a factor is necessary for normal plasma protein production (Madden, Anderson, Donovan and Whipple, 1945). Before it can be stated that folic acid duplicates the effects of liver in sprue it has to be shown that it produces gain in weight on a controlled diet in patients without diarrhoea. The beneficial effect of oral yeast extract on fat absorption is not likely to be due to folic acid, since parenteral liver extract, which contains folic acid, does not improve fat absorption. Moreover, the few observations there are on the subject do not suggest that folic acid itself improves fat absorption.

The known facts suggest that there are several distinct deficiencies in the genesis of the sprue syndrome. They are not all of the same relative importance in the study of the aetiology of the disease. In its simplest form sprue appears as steatorrhoea, usually with loss of weight. Tongue changes, anaemia and diarrhoea appear later. The fat absorption defect responds in some measure to yeast extract and to large doses of crude liver extract. Weight gain in the uncomplicated case may be produced by parenteral liver extract and possibly by folic acid. Folic acid relieves the tongue symptoms, anaemia and diarrhoea. As a provisional hypothesis it is suggested that folic acid deficiency is a common secondary deficiency in sprue, comparable to other secondary deficiencies seen in this disease, and that the basis of the primary absorption defect has not been discovered. The absorption defect may be related to an unknown substance present in crude liver and yeast extracts. Known secondary deficiencies have been uncommon in these series, but it is well recognised that the deficiencies of nicotinic acid, riboflavin, vitamin K, and probably vitamin A, as well as of minerals such as calcium and iron may occur. These deficiencies may be due to both diminished intake and deficient absorption or even to a change in the synthesis of vitamins in the bowel (Leishman, 1945). They respond well to appropriate therapy. Manson-Bahr has even claimed that nicotinic acid alone may cure sprue. In cases uncomplicated by secondary deficiencies, however, the results appear to demonstrate that neither nicotinic acid nor riboflavin has any curative value, and that the beneficial effect of nicotinic acid is probably important only in so far as it relieves or prevents symptoms of pellagra, such as the

more severe types of glossitis seen in classical sprue. Glossitis is common in deficiency states, and of manifold causation so that in a disease like sprue which may be complicated by a variety of deficiency states different forms of glossitis may be seen including those attributed to nicotinic acid and to riboflavin deficiency.

An alternative view of the genesis of the sprue syndrome, while still attributing some of the classical symptoms to secondary deficiencies, would assume that folic acid deficiency is of primary importance in the production of the syndrome. Though early cases do not show all the abnormalities which are corrected by folic acid in humans, a constant feature of the clinical history of these patients is the presence at some time of recurrent mild diarrhoea, usually not of dysenteric aetiology. It is conceivable that this diarrhoea is itself a sign of folic acid deficiency, since Carruthers (1946) has shown that a variety of types of chronic diarrhoea in the tropics can be relieved by folic acid therapy. This view would imply that folic acid deficiency leads in some way to a fat absorption defect which is not remedied when the folic acid deficiency is corrected. There is in fact not yet sufficient evidence to define the role of folic acid in the absorption defect which appears to be the fundamental abnormality in tropical sprue.

The results presented in this chapter show that sprue, as manifested by steatorrhoea and the loss of weight, may exist in the absence of other signs of disease. Many of these signs probably result from secondary deficiencies, yet it is often only in the presence of other signs, such as anaemia, diarrhoea and severe glossitis, that tropical sprue is in fact diagnosed, while the current methods used for demonstrating steatorrhoea, on the basis of the percentage composition of the faeces, are inaccurate and inadequate. Since treatment is in general likely to be more successful when given early in the disease, the diagnosis should be made at an early stage. All cases of persistent diarrhoea and loss of weight, especially if arising during the hot season should be investigated for steatorrhoea. Cases of proved bacillary and amoebic dysentery may develop sprue and so fail to respond to anti-dysenteric treatment and they represent the commonest missed diagnosis of sprue. While with a low-residue diet containing 60 g. to 90 g. of fat per day a faecal fat content exceeding 30 per cent. of the dry weight may be taken to indicate steatorrhoea, a lower fat content does not exclude steatorrhoea. In doubtful cases a limited fat balance study over a three or four day period is essential to establish the presence or absence of steatorrhoea. Facilities for this type of investigation were not in general available, but the importance of the proper investigation of steatorrhoea must be stressed, because treatment in the early stages of this disease, in the absence of complicating secondary deficiencies, is relatively simple and effective.

SUMMARY

The results of treatment in tropical sprue were assessed clinically in 62 patients. They were young soldiers with short tropical service and were mostly suffering from a mild type of the disease. Treatment

was based on a series of diets of high protein, low fat content, with addition of cooked liver or yeast extract. On this regime 23 of the patients showed complete remission and 14 were improved. The remaining 25 patients required parenteral liver therapy.

The results of parenteral therapy with nicotinic acid, riboflavin and liver extract respectively were assessed on patients who were not improving on diet alone. These patients were put on to a carefully controlled 'investigation' diet which did not include oral liver or yeast extract, and fat balance studies were made in parallel with clinical observations. Parenteral nicotinic acid and riboflavin were of no benefit in the cases, in whom specific secondary vitamin deficiencies were rarely seen. Semi-purified liver extracts were effective in controlling the symptoms of the disease and produced a rapid gain in weight in patients whose calorie intake exceeded 2,100 calories daily. Diarrhoea, when present, often stopped with this therapy, but occasionally sulphaguanidine had to be given in addition to parenteral liver and was found to be effective in controlling this symptom.

Clinical improvement was not related to improvement in fat absorption. With the parenteral liver therapy used, fat absorption improved only slowly. Nicotinic acid and riboflavin did not improve absorption. A separate study was made of the effect of a yeast extract 'Vegemite' on fat absorption when given orally (5 g. q.d.s.) in conjunction with parenteral liver extract. With this substance an improvement in fat absorption could be demonstrated in those patients who had not had prolonged preliminary parenteral liver therapy. These results are discussed in relation to work on folic acid therapy in sprue.

Early diagnosis, by the investigation of fat absorption, is thought to be important in the success of treatment.

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CHAPTER XXIV

Tuberculosis

ADMINISTRATIVE ARRANGEMENTS

Before 1941 no special facilities were provided in military hospitals for the treatment of soldiers suffering from tuberculosis. When the disease was detected in a soldier, he was expeditiously invalided out of service and his treatment after discharge from the armed forces, was considered a civil responsibility. As the incidence of the disease was considered to be higher in the civil population than in the armed forces attributability to service was seldom conceded, with the result that no disability or family pension was made admissible. This was a major source of discontentment among the troops. Moreover, the policy of discharging military personnel suffering from tuberculosis before treatment was to a certain extent responsible for the dissemination of the disease in rural areas, particularly because the vast majority of personnel were recruited from such areas.

Until 1942, the procedure for disposal of military personnel who developed tuberculosis during service, were governed by paras 267, 268, 421 and 429 of the *Regulations of the Medical Services in India.* While British troops were evacuated to the United Kingdom for disposal and treatment, the arrangements for the disposal of Indian troops remained unsatisfactory.

During the war the responsibility of the authorities to the Indian soldiers who developed tuberculosis during service began to be realised and consideration was given to the question of providing facilities for the treatment of this disease. In July 1940, an enquiry was made from the Tuberculosis Association of India and from provincial administrative medical officers (AMOs) about the total number of Indian and British officers and other ranks, who could be admitted to tuberculosis hospitals and sanitoria for the period of the war. In response to this enquiry a list of suitable institutions was supplied. During the following year, special arrangements were made with the Tuberculosis Association of India for treatment of Indian soldiers and followers who had been invalided out of the army for pulmonary tuberculosis. This was considered to be a suitable arrangement under the then existing circumstances as there was difficulty in finding trained and experienced medical staff in the army for treatment of such cases. The scheme provided accommodation for forty patients at the Lady Linlithgow Sanatorium, Kasauli. Two wards, each of twenty beds were constructed out of a grant given by the Defence Department, who also agreed to pay annual maintenance charges for those beds. In addition to this, in September 1941, the Tuberculosis Association of India placed at the disposal of the Defence Department, fifteen beds at the Lady Linlithgow Sanatorium, Kasauli, against a recurring Government grant of Rs. 20,000 for the treatment of Indian soldiers invalided from the army. This number was, however, reduced to ten in May 1947, at the request of the Central

Ministry of Health. Since 1948, the Government of India is paying the maintenance cost of fifty beds. Ministry of Defence also contributed Rs. 1·1 lakhs towards water supply of the sanatorium. VCOs, IORs and NCs(E) whose disability was considered as attributable to and/or aggravated by service conditions and who were considered suitable for sanatorium treatment, and were willing to receive treatment, were admitted to the military wards as well as to the fifteen beds (later ten beds) already reserved at the sanatorium. They were afforded treatment as serving soldiers for a period of one year.[1]

The number of Indian troops requiring treatment for tuberculosis increased considerably during the war years. There was also a fairly heavy demand for provision of suitable accommodation for European personnel (suffering from tuberculosis) awaiting evacuation to the United Kingdom and South Africa. As evacuation became increasingly difficult owing to lack of transport, accommodation had to be provided for them. A tuberculosis centre was, therefore, established at Munroe Lines, Deolali. Later on, this was merged into an IBGH which was ultimately organised as a military hospital at Aundh. Specially trained officers, nursing staff and other ranks were authorised for this hospital and special equipment, drugs and stores were made available for modern treatment. IORs were afforded sanatorium treatment at this hospital as serving soldiers for a period of one year only, but in deserving cases, sanction of the Government of India was accorded for continuance of such treatment beyond that period. Officers after their invalidment from the army were given treatment only if sanctioned by Government of India. With effect from 4 June 1945, officers suffering from tuberculosis were allowed[2] to receive treatment as serving officers for the period of the leave to which they were entitled under the regulations in force at that time. Deserving cases were, however, allowed to continue treatment beyond that period under special sanction of the Government of India. British personnel received special treatment in this hospital pending evacuation to the United Kingdom or other foreign countries.

As the policy in regard to disposal of Indian personnel suffering from pulmonary tuberculosis was to provide treatment only for those who were likely to benefit thereby, a careful selection was deemed necessary. The primary object of treatment was to enable the patient to support himself on return to civil life or at least to bring the disease under control. It was soon realised that this object was not always attainable because some patients had inadequate power of resistance to the disease and were not likely to benefit by any form of treatment, while others were temperamentally incapable of affording the necessary co-operation for treatment. It was, therefore, decided that such patients should return to their homes and should not be allowed to mix with those receiving treatment as they affected the morale of the latter adversely.

By February 1947, the following facilities for accommodation and treatment of tuberculosis patients were available :—

[1] F/2503/H (M). [2] AI(I) 731/1946.

Military Hospital, Aundh ...	For all forms of treatment including collapse and other surgical procedures.
Lady Linlithgow Sanatorium, Kasauli	For Collapse therapy and surgical cases.
CMH, Ranchi ... ... CHM, Abbottabad	For Observation, conservative treatment and later collapse therapy.
CHM, Dehra Dun	For Observation, conservative treatment and later collapse therapy, specially for Gurkha and Garhwali patients including those who were waiting to go to their homes.

Soon after the patients were diagnosed to be suffering from pulmonary tuberculosis, they were seen by a specialist in medicine. Usually this was done by the transfer of all the cases to the main hospital. Where, however, immediate transfer was considered undesirable owing to the fatigue involved, the specialist was directed to visit the patient at the institution where he was declared to be suffering from tuberculosis. In all cases, the specialist had to decide whether or not they would benefit by any further hospital treatment. Patients from the Southern Command who were likely to benefit, were transferred to Military Hospital, Aundh and those from the Eastern Command to Ranchi or Dehra Dun. The patients from the Northern Command were sent to Abbottabad and Lady Linlithgow Sanatorium, Kasauli. Patients who were not likely to benefit by treatment, were sent to their homes as expeditiously as possible with instructions regarding prevention of the spread of infection.

Patients, (including Gurkhas) who were unwilling to undergo treatment, though found suitable, were also transferred to Military Hospitals at Aundh, Ranchi or Dehra Dun for further observation and assessment, the main object being to see if they would change their mind after they had a chance to see the good results of treatment in others.

Facilities for all forms of surgical treatment were available in the special hospitals like Military Hospital, Aundh. They were freely utilised for the treatment of those cases for whom surgical procedures were indicated.

The policy regarding tuberculosis treatment for service personnel was again reviewed in 1947 and it was decided that patients suffering from tuberculosis should be invalided out of service.[3] From 28 February 1947, this order came into force and all tuberculosis patients were invalided, but were provided treatment as pensioners. This, however, did not affect the officers who were entitled to treatment for the whole period of the leave admissible to them. Individuals discharged from hospitals were not entitled to readmission to military hospitals for tuberculosis treatment. However, ex-service personnel were given all assistance from the Viceroy's War Purposes Fund available with the Tuberculosis Association of India for treatment in an approved sanatorium under the scheme sponsored by the association. The fund was meant to assist

[3] F/2603(HIM).

ex-servicemen suffering from tuberculosis irrespective of whether it was developed during service or after release from the army. The association ordinarily did not give this assistance to officers ; but genuine cases were considered on their merits when recommended for help by the association. Only those ex-servicemen who served during the war or those who were recruited before 31 March 1946 were eligible for this assistance.

EPIDEMIOLOGY

Incidence : Table I gives the admission rates per 1,000 of the strength for the India Command. The figures show a decline in the incidence of the disease amongst IORs from the year 1928 to 1939. During the war period, however, there was a steady increase in the incidence of pulmonary tuberculosis from 1·9 per 1,000 in 1939 to 2·6 per 1,000 in 1945.

TABLE I

Admissions to hospitals for tuberculosis – rate per 1,000 *for IORs, BORs and NCs(E) in the India Command* – 1928-47.

Year	BORs			IORs			NCs(E)
	Pulmonary tuberculosis	Tuberculosis Others	Total tuberculosis	Pulmonary tuberculosis	Tuberculosis Others	Total tuberculosis	Total tuberculosis
1928 ...	...	...	...	2·7	0·6	3·3	...
1929 ...	...	...	1·7	3·0	0·8	3·8	2·4
1930 ...	...	...	1·2	2·9	0·6	3·5	2·6
1931 ...	...	...	1·0	2·6	0·7	3·3	2·3
1932 ...	...	...	1·3	2·1	0·3	2·4	2·2
1933 ...	...	...	1·0	1·7	0·4	2·1	1·6
1934 ...	...	...	1·1	1·8	0·3	2·1	1·9
1935 ...	...	...	1·3	1·9	0·5	2·4	1·6
1936 ...	...	...	1·3	1·7	0·3	2·0	1·7
1937 ...	...	...	1·4	1·6	0·4	2·0	1·6
1938 ...	1·2	...	1·2	1·7	0·4	2·1	1·8
1939 ...	1·1	0·2	1·3	1·9	0·3	2·2	1·7
1940 ...	2·2	0·2	2·4	2·2	0·4	2·6	1·6
1941 ...	1·9	0·3	2·2	2·1	0·3	2·4	2·1
1942 ...	1·3	0·2	1·5	2·4	0·5	2·9	3·2
1943 ...	0·9	0·2	1·1	2·4	0·4	2·8	3·6
1944 ...	1·0	0·2	1·2	2·5	0·4	2·9	3·2
1945 ...	1·0	0·1	1·1	2·6	0·4	3·0	3·2
1946 ...	0·9	0·1	1·0	3·1	0·4	3·5	3·7*
1947 ...	...	...	2·15	3·2	0·5	3·7	4·5*

Break-up figures for BORs for the years 1929 to 1937 are not available.

*Pulmonary.

The tuberculosis incidence and mortality rate during 1918 in World War I (Cummins, 1923) are given in Table II.

TABLE II

Incidence and mortality from tuberculosis during 1918 in World War I.

Troops	Cases per 10,000	Deaths per 10,000
British and Dominion Troops	6·056	0·398
Portuguese Troops*	33·636	9·242
Chinese Native Labour Corps	36·355	13·433
Indian Troops	93·464	17·249
Indian Native Labour Corps	142·040	53·384
South African Native Labour Corps (Kaffirs)†	290·665	221·923
Cape Colony Labour Corps (Cape Boys)	444·115	103·627

*On a basis of eight months.
†On a basis of nine months.

This illustrates in a striking manner how different racial groups mingled together in the British Army in France reacted to tuberculous infection. It will be seen that morbidity and mortality from this disease were least amongst those racial groups who were highly urbanised, and highest amongst those who were drawn from communities living in comparative isolation.

Accurate data regarding the incidence of and mortality from tuberculosis amongst the Indian troops during the war years is not available for statistical analysis. Even if complete records were analysed, there will still be possibility of errors in quantitative assessment, particularly in diseases like tuberculosis mainly due to diagnostic difficulties. Certain facts, however, emerge out of the material available on superficial analysis. These are :—

(i) that there had been a significant increase in the morbidity and mortality rates from tuberculosis during the war period.

(ii) that certain racial groups, such as Gurkhas and Garhwalis produced more cases than others. This high rate amongst the Gurkhas and Garhwalis can be due to their low resistance.

It has been recognised that inheritance and environment are the main factors which may influence resistance of the individual to disease.

Environmental Factors : Gurkhas and Garhwalis ordinarily live in small villages with poor inter-communication ; therefore the chances of exposure to infection are very low.

Aspin (1947) Montoux-tested 1,580 Gurkha recruits who had never been out of Nepal and 3,324 Gurkha troops from a training battalion. In 15 to 19 years age group 23·2 per cent. of recruits and 60·9 per cent. of trained soldiers gave positive tuberculin reaction. According

to Aspin, there is little doubt that the high rate of infection in the Army in India is attributed to greater opportunities for infection in communal life of the camps and barracks as compared with the small isolated villages in Nepal the home of Gurkhas. Aspin pointed out that if Gurkhas are safely to be recruited in future, it would seem advisable to reduce the infection in barracks by periodic mass radiography, improvement of environmental conditions, and by adoption of measures that reduce the harmful sequelae of primary infection, such as BCG vaccination.

Clinical Manifestations : During World War I, it was found that 91·3 per cent. of all notified cases of tuberculosis among British troops in France were pulmonary. For the same period, the mortality for pulmonary tuberculosis in the male population of England under local conditions amounted to 91·6 per cent. of the total, a figure corresponding closely to the incidence ratio in France. It would, therefore, seem that the elimination of infective individuals by careful examination and rejection of recognised cases had but little effect in altering the proportion of cases of tuberculosis. It proves conclusively that at least in so far as British troops were concerned, the vast majority of the soldiers who developed the disease must have had their first infection prior to joining the expeditionary force in France.

The figures given below for the incidence of tuberculosis by clinical types in Indian and British troops during World War I in France (Cummins, 1923) are of great epidemiological interest :—

TABLE III

Incidence of tuberculosis by clinical types during 1917 in World War I.

Variety	British troops	Indian troops
Pulmonary tuberculosis ...	91·3 per cent.	44·6 per cent.
Glandular	1·4 ,, ,,	43·8 ,, ,,
Meningeal	1·4 ,, ,,	0·85 ,, ,,
Bones and Joints	0·84 ,, ,,	1·28 ,, ,,
Abdominal	2·5 ,, ,,	9·3 ,, ,,

It will be seen from the above table that whereas the pulmonary type predominated in the British troops, the percentage of non-pulmonary types in Indian troops were actually higher than that of the pulmonary type. Commenting on this, Cummins (1923) in the *Official History of the great War* has stated as follows :—

> " The Indian races drink large quantities of milk, but it is generally recognised that the cattle of India are practically free from tuberculosis. The evidence cited to prove this point by Dr. Lancaster in the work already quoted is conclusive. It would appear that the Indian soldiers in France purchased large quantities of milk in the villages in which they were billeted, and it cannot be doubted that this milk was frequently infected. It is tempting to speculate as to whether their marked liability to glandular infections was not connected with the ingestion of infected

> milk by adults who were hitherto 'virgin soil' to the bovine bacillus. It is interesting to note that the tuberculous meningitis of childhood in England is chiefly human in origin. It is to be hoped that light may yet be thrown upon this point by the search for bovine strains amongst glandular cases returned to India from the European theatres of war. Colonel Glen Liston and his assistants have examined many strains from tuberculous adenitis arising in natives in India without finding any instance of bovine infection and the discovery of a large proportion of such strains amongst men returning from France would be of great interest in this connection".

During World War II also, the ratio of the incidence of non-pulmonary types to pulmonary types for Indian troops was slightly higher than the similar ratio for British troops. It will be seen from the figures given in Table I that in the year 1943, the figures for BORs were 0·9 for pulmonary tuberculosis. On the other hand, the figures for IORs were 2·4 for pulmonary tuberculosis and 0·4 for non-pulmonary tuberculosis. It will, however, be seen that the incidence of non-pulmonary types in the Indian troops during World War II was much less than the incidence in World War I.

As regards the clinical types of pulmonary tuberculosis seen in the IORs, Beal (1945) has summarised his impressions as follows :—

> "Firstly, large number of cases have been labelled as suffering from pulmonary tuberculosis on very flimsy evidence. Secondly, the definitely tuberculosis cases in the main, fall into the groups of T.B.+2 and T.B.+3 i.e. moderately advanced and advanced cases of pulmonary tuberculosis. A third feature has been noted in the rapid spread of the disease in the Gurkhas. A fourth feature has been the incidence of tuberculosis in medical personnel".

The impression of medical specialists who worked in Indian general hospitals during World War II has been, that most of the cases of pulmonary tuberculosis seen amongst the Indian soldiers were of the post-primary type. The exudative variety was more common than the productive type. This only reflects the situation regarding the relative proportion of the exudative varieties as seen among the civilian population. Though, tuberculosis has been prevalent in India for centuries, it was confined to isolated groups of population, so much so tuberculosis practically remained unknown until recently in major parts of rural India. Consequent on rapid urbanisation and industrialisation during recent years and the availability of better and more rapid means of communication, the uninfected portions of the population have been infected with tuberculosis during the last few decades. The other reason for the prevalence of the less resistant types of tuberculosis in India, is the state of chronic undernutrition and malnutrition in which the vast majority of the population live. That nutrition plays an important part in determining the clinical type and consequent outcome of the disease is shown by the fact that in the occupied areas in Europe where people were living under famine conditions during the whole period of war, the type of tuberculosis seen was of the more fulminating variety.

So far as the army is concerned, nutrition cannot be blamed for the type of tuberculosis, seen in the Indian soldier. The Indian soldier put on weight and gained in strength as the army provided

better type of diet both in quantity as well as in quality, than the type of food which he was accustomed to at home. And yet the number of exudative type of tuberculosis seen in the army was more or less the same as that obtained in the civilian population.

It was among the Gurkhas that one frequently met with the primary type of tuberculosis. The acute miliary type of tuberculosis was relatively more common among the Gurkhas than among others.

Cases of primary pleurisy were not uncommonly met with among Indian soldiers. Most of the cases of primary pleurisy are tuberculous in origin. During 1945, out of 1,256 cases treated in the medical division of No. 131 IBGH, 62 cases were of primary pleurisy. Out of these three cases developed signs of miliary dissemination during their stay in hospital. All the remaining cases had no visible pulmonary lesion. The chest condition also cleared up sooner or later in all the cases. They were all diagnosed as cases of primary tubercular pleurisy. These and similar cases of primary pleurisy must have developed primary tuberculous infection during the course of service in the army.

The facilities and opportunities provided by the army should have made the detection of early cases of tuberculosis comparatively easy and yet the vast majority of the cases were seen in the moderately advanced and very advanced stages of the disease. It seems that early symptoms of tuberculosis were mistaken for minor ailments like common cold, bronchitis or influenza. Very often soldiers in the field when they developed slight fever or complained of feverishness were not taken seriously by the RMOs who owing to exigencies of field service ordered them back to duty. A soldier, if he had only a slight cough, carried on with his work, though not as efficiently as before, until he was completely incapacitated. As the majority of cases were of the post-primary type with insidious onset, chances of making correct diagnosis, particularly under field conditions were rather remote. Diagnosis of tuberculosis was made in such cases only when the disease was sufficiently advanced. On the other hand, cases with sudden onset and urgent symptoms had better chance of being detected early as they were necessarily admitted to hospital. Cases with onset of acute pleurisy came early under observation of the medical officer. Owing to the urgency of symptoms, all these cases were admitted to hospitals where facilities for diagnosis were readily available. There is also another side of the story. A large number of cases were sent to the Tuberculosis Centre in Kirkee wrongly diagnosed as tuberculosis on very flimsy grounds. This was mainly because during the early days of the war, medical officers were criticised for not detecting cases of tuberculosis in the early stages. The directive given to various hospitals in the India Command that all early cases of tuberculosis should be evacuated for treatment to Tuberculosis Centre at Kirkee might also have had a similar effect, owing to the anxiety on the part of the medical officers to detect incipient cases.

The clinical course of the disease in the Indian soldier does not differ materially from that which is observed in the civil population. It may be added that a patient with extensive lesions in the lung may not show any toxic reaction. On the other hand there were cases with

no demonstrable lesions radiographically but exhibited symptoms of toxaemia. It has been found that the Indian soldier is not very amenable to bed rest. This necessarily has an adverse effect on prognosis especially when conservative forms of treatment are adopted. In the experience of the Tuberculosis Centre at Kirkee, the reluctance to bed rest and the call for village life proved too strong for many IORs who got discharged against medical advice. Those who submitted themselves to surgical treatment definitely improved.

PREVENTION

During war time when recruitment has necessarily to be intensive, sure but quick methods of medical examination have to be adopted. Perhaps the quickest and the surest way by which recruits to the armed forces can be screened for tuberculosis is by mass miniature radiography. Avoidance of overcrowding in barracks at the bases, periodic screening for tuberculosis by mass radiography, and isolation and treatment of those who are detected to be suffering from the disease are the most important methods which ought to be adopted for prevention of tuberculosis in the armed forces. In addition, compulsory vaccination with BCG of non-reactors to tuberculin test will largely contribute to a reduction in the incidence of tuberculosis particularly of the primary infection types. Detection and elimination of the sources of infection will undoubtedly lead to elimination of the disease from the armed forces. Under the existing circumstances, however, the process may be difficult, but it is not beyond the bounds of practical possibility.

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CHAPTER XXV

Typhus Group of Fevers

Classical typhus had repeatedly made its appearance in an epidemic form in the military history of the West, but during World War II *tsutsugamushi* disease (scrub typhus) suddenly made its appearance in different parts of the India Command and SEAC and rapidly became a military medical problem of the highest importance. The existing knowledge of the disease at that time was rather incomplete ; therefore one could neither surmise where next it would make its appearance nor advise adequate preventive measures.

The explosive outbreak in Ceylon in December 1943, in an East African brigade alarmed all concerned and in a conference held in Ceylon in February 1944, the need of forming research teams to investigate various phases of the problem, was stressed. The Australian forces had been getting cases and their research workers were already in the field. In 1943, McCulloch had made his valuable contribution in the use of dimethyl phthalate (DMP) and dibutyl phthalate (DBP) as miticides. In October 1943, the USA Typhus Commission had gone to New Guinea and another was sent to North Burma in 1944. The United State Navy sent a team to South Pacific area. Valuable contributions came from these sources.

The GHQ, India initiated the Base Typhus Research Laboratory at Poona (D. R. Seaton and M. G. P. Stoker) and the field team (S. L. Kalra) in 1944. The Medical Research Council (MRC) was asked for assistance. The MRC Typhus Commission (R. Lewthwaite, Field Director) arrived at Headquarters Supreme Allied Commander, South East Asia in July 1944. The original members of the Scrub Typhus Commission were Dr. Kenneth Mellanby and Squadron Leader C. D. Radford. Kalra and Radford started work in Addu Atoll in 1944. In the meantime SEAC initiated a new unit the Scrub Typhus Research Laboratory in 1945, to be based in Imphal, when all joined it to form a composite team, including a mammalogist (M. L. Roonwal) selected by GHQ.

The staff included the following :—

Dr. Kenneth Mellanby.
Dr. H. C. Browning.
Mr. K. L. Cockings, Friends Ambulance Unit.
Mr. T. M. Gordon.
Lieut.-Colonel J. R. Audy, RAMC.
Squadron Leader C. D. Radford, RAF.
Flight Lieutenant A. A. Bullock, RAFVR.
Major H. M. Thomas, RAMC.
Captain H. C. Steward, RAMC.

GHQ Field Typhus Research Team.
Major S. L. Kalra, IAMC.
Major M. L. Roonwal.

Technicians and general duty personnel.
12 NCOs.

The following account first deals with the state of knowledge of typhus fevers in India at the beginning of the hostilities and then the clinical accounts published by the army medical officers, the investigations carried out by the above composite team (scrub typhus research laboratory) and the investigations of GHQ field team continued in India after August 1946.

STATE OF KNOWLEDGE OF SCRUB TYPHUS AT THE ADVENT OF HOSTILITIES

The disease had long been known in Japan and China as *tsutsugamushi* disease. Since 1879, investigators in Japan, Formosa and later Dutch workers in the Netherlands East Indies had recorded certain salient facts regarding its epidemiology and causal organism. It was suggested that the infectious agent was introduced into man through mites finally described as *Trombicula akamushi* (Tanaka, 1899). Miyajima and Okumura (1917) confirmed this suggestion by allowing laboratory reared larvae of *Trombicula akamushi* to attack and feed upon a Japanese monkey which subsequently developed a febrile condition believed to be an homologue of the *tsutsugamushi* disease.

The disease, also called Japanese River fever, or Flood fever, had a strict seasonal incidence and was restricted to individuals working on lands from where the flood water had receded. These restricted foci were called *yudokuchi* or noxious areas by the Japanese, tending to make scrub typhus an occupational disease. Monkeys and other experimental animals exposed in the endemic areas became infested with mites and some of these monkeys developed 'typical' illness. Kitashima and Miyajima (1918) noted that recovered monkeys were refractory to re-infection. Nagayo, Miyagawa, Mitamura, Tamiya and Tenjin (1921) produced further evidence incriminating the mite as vector by injecting suspensions of adult *T. akamushi* collected in nature and larvae reared in laboratory into monkeys and producing the infection. Kawamura (1926) also produced infection in a monkey by allowing laboratory reared larvae to attach; a typical eschar or primary sore being produced at the site of attachment.

In 1931, Kawamura and Imagawa could recover the infectious agent from the spleen of naturally infested voles, *Microtus montebelloi* Milne-Edwards.

Nagayo, Tamiya, Imamura, Sato, Miyagawa and Mitamura (1924) described the aetiological agent as diplococcus like and short rod forms, observed in smears and sections from primary eschars and other infected animal and human tissues stained by Giemsa's method and Azure II. The presence of rickettsiae as the aetiological factor was confirmed by Ogata (1931) who had demonstrated it in the testes of infected rabbits and named the organism as *Rickettsia tsutsugamushi*. The name *Rickettsia orientalis* was subsequently given to it (Nagayo, Miyagawa, Mitamura, Tamiya, Sato, Hazato and Imamura, 1931).

In the Netherlands East Indies, 'pseudo-typhoid' of Deli in Sumatra was soon recognised to be a variety of *tsutsugamushi* disease and Schuffner (1915) suspected that the disease was carried to man by a

mite. Walch (1923) described the mite as *Trombicula deliensis*, closely allied to the *T. akamushi* of Japan. A further epidemiological finding was that the disease primarily occurred among labourers who were engaged in clearing waste lands and neglected estates overgrown with scrub such as *lalang* grass but seldom occurred in workers in the primitive forest.

It was recognised that *R. tsutsugamushi* also existed in Malaya, having a rural distribution in scrub similar to that in Sumatra. Fletcher, Lesslar and Lewthwaite (1928) found large numbers of *T. deliensis* infesting wild rats in areas where the disease occurred. The identity of *tsutsugamushi* disease with rural or scrub typhus, from which it used to be differentiated by the absence of eschar in the latter, was soon established by serological methods as both agglutinated *Proteus* OXK, whereas sera from typhus cases in urban areas agglutinated *Proteus* OX19 (Fletcher, Lesslar and Lewthwaite, 1929). Lewthwaite and Savoor (1936) isolated two strains of rickettsiae, exhibiting cross-immunity with human strains, from wild brown rats trapped in endemic scrub areas, thus providing evidence that the rodents were the reservoirs of the causative agent. From further experiments, Lewthwaite and Savoor (1940a) proved conclusively that Sumatran mite fever, *tsutsugamushi* disease and 'rural or scrub typhus' of Sumatra and Malaya were one and the same disease though the latter were characterised by the absence of a primary ulcers. Lewthwaite and Savoor (1940b) pointed out that the primary sore may be so slight as to be missed or may have disappeared at the time of examination and suggested that the name *tsutsugamushi* disease should be applied to all.

The disease also occurred in Formosa where Morishita (1939) recorded a series of 166 cases during the period 1933-38. It occurred among adult males whose occupation brought them into infected areas in the valleys, near villages and plantations, whereas in the nearby Pescadores, the infected areas were confined to grassy patches in the domestic gardens with the result that children were the victims. Cases of scrub and murine typhus had been reported occasionally in medical administrative reports of Ceylon from 1936 onwards.

Thus, at the advent of hostilities with Japan, the disease had a fairly wide distribution in the Far East but it was mostly a 'silent' disease of rural areas, being confined as a 'zootic' to the rodent population which served as hosts of the *trombiculid* mites, occasionally the infection being carried to interlopers such as labourers or peasants who obtruded on scrub areas or flooded lands. But when troops in their thousands began to supplant the rodents as hosts, the disease began to assume epidemic proportions.

TYPHUS IN INDIA

In 1852, Lyell (1854) and Farquhar (1855) described cases of typhus in Yusufzai country and Wallick (1855) recorded cases seen by him at Kohat.

Eyre reported in 1857, that in the registers of His Majesty's hospital at Gooty (in the district ceded by Nizam to the British) 15 admissions of typhus cases were recorded in 1808, from the garrison stationed there.

From 1860-69, there appears to be some confusion about the differential diagnosis of typhus cases, and controversy regarding their very existence in India, although cases were seen at Hazara, Rawalpindi, Ajmer, Lucknow, Agra, Calcutta, Madras and Bombay. From the clinical description of these cases there is no doubt that these were typhus cases, and one can easily surmise even the types. Walker (1861), Grey and DeRenzy (1863), and Bateson (1867) mistook louse-borne relapsing fever for typhus, which was correctly pointed out by Smith (1867). This misunderstanding may have arisen due to both diseases being present at the same time and the vector-louse being common.

Morehead in his book *Researches on Diseases in India*, published in the first half of the nineteenth century wrote " The typhus, typhoid and relapsing fever of Dr. Jenner are unknown in India ". Scriven (1856) contradicted it and published clinical accounts of typhus cases seen by him. Wallick (1855) in his notes on cases at Kohat, and Lyell (1854) and Farquhar (1855) in their description of an outbreak in Yusufzai territory did not mention rash in their description, though the rest of the clinical picture was that of typhus. Greenhow (1858) saw cases of typhus in the British community during the siege of Lucknow in 1857 ; about Indians he said in his notes " I may be permitted to add that, among natives also I believe I have met this complaint in its true form ". Chuckerbutty (1864) published detailed clinical description of 12 cases, 10 foreigners and 2 Indians, admitted in the Medical College Hospital, Calcutta. Moore (1870) wrote that typhus was now infrequent in India, but he had seen a definite case in Bombay. Fairweather (1869) reported cases in Rawalpindi jail, in which he also described the rash.

The next record of typhus appears in the *Statistical Report for* 1878 edited by Bryden (1879). This is followed by an important paper on typhus by Rice (1883). This paper was actually compiled by Surgeon Major R. T. Wright from the reports of Surgeon Major W. R. Rice, civil surgeon Jubbulpore, placed at his disposal by Deputy Surgeon General W. Watson. Two epidemics—one at Saugor in 1859, and the other at Jubbulpore in 1865—are described and it is also stated that occasional cases were seen at Jubbulpore and neighbouring towns. The epidemiological observations and clinical notes by Rice are unmistakably that of typhus. This article also shows that while some denied the existence of typhus in India, others were firmly convinced of its presence. This paper was published in 1883, but the observations made in it were most probably written sometimes in 1865, when Rice had observed two epidemics besides sporadic cases. For the next eleven years nothing was recorded in literature and one might think that the controversy was over, but the problem was by no means solved. In 1894, Surgeon Captain Harold Hendley read a paper before the Indian Medical Congress, which was published in 1895. In the introduction he remarked " Whether typhus fever is one of the many diseases we have to fight against in India is a question that has often been asked ; and though we in the Punjab have no hesitation in answering in the affirmative our assertion is met with doubtful questioning elsewhere ".

He stated that there had been nine epidemics in the last fifteen years in Peshawar Valley, and gave an account of the 1891-92 outbreak. He suspected that this outbreak was started by a single case imported from Kabul. He also mentioned that in the same year in upper Kulu or Plach the incidence had been unprecedented from January to March resulting in 626 deaths. Pisani (1895) read a paper at the Indian Medical Congress on ' Typhus fever in Mardan and Baluchistan '. He reported some of the epidemics that occurred between 1888-94, and summarised that typhus was endemic in Trans-Indus districts from Yusufzai, Hazara, and the Himalayan hill tracts to Kulu. Quill (1895) reported an isolated case in a British soldier at Deolali. The nineteenth century closes with this record of unpublished denials and doubts and published assertions.

The twentieth century opens with a paper by Husband and MacWaters (1908). They described an outbreak in the 1st Mule Corps at Peshawar (1905) which had returned from a mission in Tibet. In the following year there was a further epidemic affecting the 1st Mule corps and later 6th Mule corps, ending with a total of 120 cases. They also refer to cases at Malakand, Chakdara, and Kulu Valley. Hepper (1908) reported cases in Peshawar jail. Mitra quoted by Basu (1924) read papers on typhus before Calcutta Medical Club in 1912 and 1917. He could not incriminate lice and found no positive OX19 in his cases. The latter test was probably not performed repeatedly, or his cases were scrub typhus which was known to be endemic in certain suburbs of Calcutta. Bradley and Smith (1912) diagnosed typhus in a British patient at Jaffurpur near Calcutta. The editor *Indian Med. Gaz.* (1915) has published abstracts from the annual report on the work of Punjab hospitals for 1914, signed by Bamber. In these typhus is mentioned at Kot Chandra in Mianwali district, a small village on river bank and in the neighbouring villages of Khudozai and Jalalpur. From January to middle of May 1914 there were 142 cases with 59 deaths.

In 1913, McKechnie (quoted by Megaw, 1921) was placed on special duty at Bhim Tal and Sat Tal to investigate enteric and relapsing fever, for the lakes were well known for mahaseer fishing and were popular with anglers in the Indian Army. McKechnie came across 26 cases of typhus during his stay, which were first pointed out to him by Assistant Surgeon Hardy, and after the first disbelief he agreed with the diagnosis. An exhaustive report of his investigations was submitted to the Government of the United Provinces, and though important remained unpublished. Megaw came across this unpublished report and himself suffered from typhus in 1916. He noticed an attached tick on 1 July 1916, which he thought he had picked up while sitting on a grassy plot between Bhawali and Sat Tal. The fever began on 21 July 1916, at Lucknow. He wrote an article in 1917, in which he expressed the opinion that his own case was Brill's disease, but incriminated tick as the probable vector, with a cautious note ; " if afterwards it turns out to be a different disease no great harm will be done ".

In this paper he gave no reference to any previous publication but rather passed the following remarks. " This note has been written

with a view to attract attention to an interesting unclassified fever of India, and in the hope that those who come across cases of it may be stimulated to further enquiries regarding it, and so remove one more fever from the objectionable class of 'pyrexia of uncertain origin'. So far as I know McKechnie's description is the first clear account of the fever as it occurs in India".

Epidemics that had all the characters of a louse-borne typhus were (1) Saugor (1859) described by Rice (1883); (2) Peshawar and Kulu Valley (1891) by Hendley (1895) and (3) in the 1st and 6th Mule Corps at Peshawar by Husband and MacWaters (1908). In the second one at Peshawar the starter case was traced to Kabul, and the third was considered an importation from Tibet. The one at Kulu could have spread down from Ladakh or farther northern territories. Most of the records refer to outbreaks at Peshawar or other areas in the North West Frontier of India. Pisani (1895) summarising previous records came to the conclusion that typhus was endemic in Trans-Indus districts from Baluchistan to Yusufzai and Hazara, and in the Himalayan hill tracts especially Kulu Valley. If Kashmir is also included, which has been mentioned in the earlier records by Husband and MacWaters (1908); it becomes a geographical continuity from Baluchistan to Kulu. It is possible that by frequent importation, it became endemic and is still existent. The recent outbreak in refugees at Srinagar (1947-48) supports this contention. For in this instance, there was no evidence of introduction from outside, but circumstances had provided suitable conditions for its spread.

Saugor, where the biggest outbreak occurred, was a great favourite station with Europeans. The outbreak started in the European community, spread to the locals, and occurred before any other big epidemic in India. Rice (1883) states "during this fever, hospitals were established in the city of Saugor, and in the cantonment bazar, because whole families were stricken at the same time and none were left to nurse the sick". It is possible that in this instance it was introduced from England. Typhus was still common in that country in those days. According to Zinsser (1935) in Ireland in 1816-19, there were 7,00,000 cases. In London there was an outbreak in 1862, which Zinsser assumes may have been introduced in 1856, with soldiers returning from Crimea. Importation of infection from one distant country to another by the slow moving ships of those days was possible. In Mexico it was introduced by ships from Spain in 1570. The infected lice will not survive the journey, but we know that rickettsiae can survive in the louse faecal dust for long periods, or a case of Brill's disease could start the infection. Cleanliness as a virtue began to be recognised in the world in the last half of the nineteenth century; before that period lousiness was not confined to any particular strata of society. According to an editorial (1908) in the *Indian med. Gaz.* typhus was still common in Edinburgh and Dublin. Rice (1883) says that he had only recently been familiar with it in Ireland.

Saugor and Jubbulpore jails were the only recorded places of large scale epidemics outside the north and north-western endemic belt. Epidemic typhus cannot establish itself in the warm plains of

India, particularly Bengal, Central Province and the country south of it. For heat and perspiration, frequent bathing and scanty clothing are not favourable to the propagation of lice. In the North West Frontier Province, Punjab, Kashmir, and Kulu Valley, due to severe winter, people are more heavily clad and provide conditions suitable for lice ; therefore the infection can easily become endemic.

There is enough evidence to show that murine typhus was also present during the period under review. Some of the cases were isolated ones like that of Quill (1895) at Deolali and Bradley and Smith's (1912) case at Jaffurpur. There was no evidence of contagion in Greenhow's (1858) cases during the siege of Lucknow in 1857. The infections in the jails of Rawalpindi and Ajmer were not explosive in character. Chuckerbutty's (1864) cases at Calcutta were both Europeans and Indians and from different parts of the town ; and he failed to find any evidence of contact between different cases. Rice (1883) has mentioned that in Jubbulpore district single cases occurred in a family and were more prevalent in the narrow crowded lanes of towns and villages. The typhus season mentioned in most of these instances was spring and early autumn.

The only cases, that can be reasonably pointed out to be scrub typhus are those of McKechnie's at Bhim Tal and Sat Tal lakes in the Kumaon hills. Megaw (1921) thought that these cases were tick typhus. Cragg (1922) expressed an opposite view and tried to build a *prima facie* case against the louse, on very poor grounds. Howlett (quoted by Megaw, 1921) investigated this area in 1912, and failed to find evidence of typhus in the local population. McKechnie himself found no evidence of tick bites and expressed no opinion about the vector, except saying that the disease resembled typhus in every respect. Kalra and Rao (1948) investigated these lakes and proved that it was primarily a scrub typhus area, and the vector mites were present more or less in the vegetation on the door steps of the houses. The first strain was isolated from mites recovered from the compound of the dak bungalow at Bhim Tal. The topography of the vegetation was probably not very different in 1913. McKechnie says " in Sat Tal the cottages occupied by visitors during the season are situated in the dense jungle each having a very small clearing around it ".

Megaw (1917) in asserting that McKechnie's cases were tick typhus was probably influenced by these factors. The ecology of scrub typhus known at that time was that of *tsutsugamushi* recently described by Japanese workers. There it was confined to flooded banks of rivers and had high mortality of nearly 55 per cent. Rocky Mountain spotted fever was also described during that period in the USA, and Megaw considered that the terrain at Bhim Tal was identical to Rocky Mountain and this forms the main argument of his thesis. The most firm conviction probably came from his own case, for he was bitten by a tick in the same area between Bhawali and Sat Tal.

Later Megaw (1924), Megaw, Shettle and Roy (1925) and Megaw and Sundar Rao (1928) described 50 cases of typhus in which only 10 had history of tick bite. In 1932, Biggam described three cases, in

none of which he could incriminate the tick; whereas Christian in the same year obtained positive evidence of tick bite in one case. Blewitt (1934) described 13 cases in Ahmednagar in two of which there was evidence of tick bite.

The next advance was made in 1933, when AHQ (India) directed all army laboratories in India to carry out Weil-Felix test as a routine in all cases of fever. And from the analysis of one year's study, they (in their annual report of 1934) classified typhus fevers in India into three groups as follows. These findings were later published by Boyd (1935).

1. *Scrub Typhus :* Scattered throughout India, with seasonal incidence in late monsoons from mid August to beginning of October ; rise in OXK agglutinins only.
2. *Tick Typhus :* Starting in July and rising to a maximum in December, in South India. The symptoms are severe, the rash is present on palms and soles also, persisting for two to three weeks and in some cases for a month or more. The serological results are variable, agglutinins for OX2 predominate, in others the balance is in favour of OX19. No eschar present.
3. *Flea-Borne Probable :* In South India ; rash is transient, of varied type and distribution, or absent. The disease is absent during the hot weather months. High OX19 in most cases.

Macnamara (1935) reported a group of cases from the Simla hills, giving a significant agglutinin titre against OXK. Covell, also working in Simla, progressed further from serological studies to isolation of rickettsiae. In 1936, he isolated a strain of murine typhus from the pooled brains of three rats from Simla hills; and with Mehta (1936) succeeded in infecting human lice with this strain. In connection with scrub typhus, Covell (1936) noted that the disease occurred as focal outbreaks in rural or semi-rural areas in Simla hills, immediately after the rainy season. His colleague Mehta (1937) observed that *T. deliensis* infested wild rats throughout the area and was particularly abundant in the rainy season and on epidemiological grounds regarded it as the probable vector. Bush (1936) also recorded cases of scrub typhus in Simla hills. Webster (1940) isolated rickettsiae from a patient at Simla who gave a high OXK agglutination. He also isolated a strain from wild rats that produced OX19 agglutinins.

Further reports of murine typhus were published by Bhatia (1940) at Lucknow ; Patel (1940) at Bombay ; while Sharma (1940) published notes on a series of cases collected from 1936 to 1938, in which 50 were OX19 type, five were OX2 and one imported case was OXK.

In the beginning of the war the knowledge of typhus fevers in India can be summed up as follows. Epidemic typhus which at one time prevailed in the plains of India, had disappeared from there but was probably still present in Kashmir. Murine and tick-typhus were scattered all over the country but the incidence was low ; and the rickettsia of murine typhus had been isolated from rats. The existence of scrub typhus had been established in Simla hills, and a strain had been isolated from a patient.

During 1941-42 Heilig and Naidu described 32 cases of typhus from Mysore and Nanjangud, which in their opinion were murine typhus. The sera of three random patients were sent to Topping in the USA, who found that Rocky Mountain spotted fever antigen was fixed in higher titre than murine typhus antigen (Topping, Heilig and Naidu, 1943). But a strain isolated by them from a patient was studied by Savoor at Haffkine Institute who came to the conclusion that it was murine typhus. It is possible, therefore, that in their series they had both tick-typhus as well as murine typhus cases.

Patel, J. C. (1943) reported five cases of murine typhus and one of scrub typhus from Bombay. Patel, N. D. (1943) reported six more cases of murine typhus from Bombay. King Institute Guindy during their examination of sera from Madras came across some giving positive Weil-Felix reaction. Bardhan (1944) collected a record of 41 cases of typhus in military personnel in the United Provinces from 1937 to 1942. His cases were from Lansdowne, Jhansi, Nowgong, Mathura and Agra ; and all were serologically scrub typhus.

In the winter of 1942-43 there was a severe outbreak of presumably epidemic typhus in Kashmir Valley, started by the entry of Kazaks from the neighbouring territory of China. The total incidence in this epidemic is not known but Hussain (1945) reported one series of 1,526 cases with 408 deaths and another of 946 cases with 320 deaths. The incidence was high amongst Gujjars, a cattle-keeping community living on the hill sides and more heavily louse infested than others. Jackson (1945) reported 213 cases of epidemic typhus with five deaths from the Agency Headquarters station hospital at Gilgit during the period November 1943 to August 1944. Probably this was an extension of the Kashmir epidemic. The diagnosis in the above reports was based on epidemiological evidence and Weil-Felix test carried out in a few cases.

Historically the knowledge about typhus fevers in India progressed by four stages. (1) From 1805 to before 1917 typhus was diagnosed clinically and all cases were considered to be louse-borne. (2) From 1917, first Megaw and later others tried to associate it with ticks. (3) In 1933, Army Headquarters (India) introduced serological methods and based on clinical, serological and epidemiological findings suggested further classification into three types. (4) In 1936, Covell and Webster advanced the knowledge still further by isolating rickettsia from rodents and patients, and Mehta by finding *T. deliensis* in Simla hills.

In other countries typhus always claimed lives from amongst those engaged in its investigation or control of epidemics. India also was not spared. Surgeon Major J. R. Johnson died of typhus in 1868 in the Hazara epidemic. Major F. W. Cragg, IMS investigated an epidemic of probably louse-borne typhus in Kashmir during the winter of 1923-24. He fell ill with it on his way back to Lahore and died on 23 April 1924.

TYPHUS IN THE ARMY IN INDIA BEFORE AND DURING THE WAR

Table I gives the incidence of typhus fever among IORs since 1933.

TABLE I

Incidence of typhus fever among IORs in the India Command—1933-1946.

Year	Actual	Rate per 1,000
1933	19	—
1934	51	—
1935	45	—
1936	48	—
1937	43	—
1938	38	—
1939	42	0·4
1940	31	0·2
1941	31	0·1
1942	33	0·1
1943	140	0·2
1944	231	0·3
1945	373	0·4
1946	191	0·3

TABLE II

Results from agglutination tests for cases of typhus fever among IORs in 1945 *and* 1946.

Year	X19	X2	XK	Clinical	Total
1945	125	17	239	91	472
1946	125	18	112	23	278

During the period 1938 to 1941, there were 142 cases of typhus reported among IORs, of which 48 were of the OXK type, 68 of the OX19 type, 17 of the OX2 type and the remaining 9 were unclassified.

Tables III and IV show the incidence of typhus fever in the Indian Army during 1945-46 :—

TABLE III

Comparative statistics of the incidence of different types of typhus fever among Indian and British troops and civilians of the Army in India during 1945-46.

Year	Flea-borne		Tick-borne		Mite-borne		Clinical		Total
	Number of cases	Percentage	Number of cases	Percentage	Number of cases	Percentage	Number of cases	Percentage	
1945	161	22·8	32	4·5	370	52·5	143	20·2	706
1946	134	42·5	25	7·9	124	39·4	32	10·2	315

TABLE IV

Distribution of different types of typhus fever cases in various parts of India during 1945-46.

Provinces	Type of Typhus									
	Tick-borne		Flea-borne		Mite-borne		Clinical		Total	
	1945	1946	1945	1946	1945	1946	1945	1946	1945	1946
Bengal and Assam	2	1	14	13	310	76	45	7	371	97
Punjab and North West Frontier Province	1	2	45	47	7	13	7	7	60	69
Bombay Presidency	10	2	55	30	14	14	25	10	104	56
South India	10	6	30	31	18	6	54	1	112	44
Central Provinces	6	11	7	6	13	3	7	4	33	24
United Provinces	3	3	10	7	8	12	5	3	26	25
All India	32	25	161	134	370	124	143	32	706	315

Note : The figures in Table IV are total figures for Indian and British troops and civilians treated in military hospitals. The total figures of different provinces are, therefore, not comparable with each other—only the relative incidence of different types is of value.

Table IV indicates that mite-borne typhus is specially prevalent in the humid regions of Bengal and Assam which are the main scrub typhus provinces of India. Kalra (1947) observed that if these provinces and Himalayan foot-hills were excluded, then murine typhus would be the chief problem in the rest of India. Scrub typhus cases were specially prevalent during the months of July to November, indicating a definite seasonal incidence corresponding to the period of maximum rainfall. From the available evidence, tick typhus appears to be least important as it has the lowest case incidence and strains are not highly virulent. Two strains had been isolated, one from a patient in Poona by Seaton and the other by Kalra from nymphs and adults of the tick *Haemaphysalis leachi* var *indica*, taken from a rat trapped at Palel near Imphal. These strains showed antigenic relationship to *Dermacentroxenus rickettsi*, causal organism of Rocky Mountain spotted fever, but they produced very mild symptoms in inoculated guinea-pigs.

TYPHUS IN THE SEAC

In World War II, mite-borne or scrub typhus proved to be a great risk to the Allied armies operating in the SEAC and in the South West Pacific. Since 1942, the disease literally bogged the footsteps of the troops operating in scrub in these areas whether in actual combat or on training manoeuvres in the jungle. From comparative obscurity the disease emerged very rapidly into notoriety having a mortality rate of 10 to 15 per cent., a high incapacitation rate and a depressing psychological effect (Megaw, 1945).

The first outbreak was recorded by Singh (1945) at Meiktila (Burma) in September 1941. There were 107 cases in a battalion with two deaths. Typhus cases were reported from Calcutta and Ranchi areas during the period 1942-43. The cases reported from Calcutta and its suburbs were either sporadic in nature occurring throughout the year or a series of unit outbreaks of varying intensity occurring in the later half of the year. In the autumn of 1942, twenty cases with four deaths were reported from 'The Royal Warwicks' stationed in the suburbs of Calcutta (Parker, 1947). All the cases, except one imported from Ranchi gave a positive OXK agglutination. In Ranchi 35 cases occurred among British troops during jungle exercises. There was a history of tick bite in the case of two officers. Bowes (1943) described 33 of these cases occurring at Chipadohar or Chaibasa Road as tick typhus since Weil-Felix reaction was positive to OX19 and OX2 and doubtful to OXK.

During the period June to December 1943, Lusk (1945) reported 114 cases from the Calcutta area. Majority of these cases, numbering sixty, were in the form of unit outbreaks in two Indian regiments viz., the 2/8th Punjab and 6/11th Sikhs stationed at Jhingergacha, about eighty miles away from Calcutta. The remaining fifty-four cases were from Calcutta and its suburbs. Serologically ninety-six of these cases, fifty-five from Jhingergacha, and forty-one from Calcutta, were OXK in type with eleven fatalities. Twelve cases, probably flea-borne, were of the OX19 type with no fatality. One case which proved fatal was OX2 in type. The remaining five cases, all of which proved fatal, were serologically negative but were diagnosed as typhus from clinical and post-mortem evidence.

Krishnan, Smith, Bose, Neogy, Ghosh Roy and Ghosh (1949) reported that the scrub typhus in the Barrackpore area was prevalent during the rainy season from May to October. Examination of trapped rats showed that 24 per cent. harboured *T. deliensis*, and of these, 20 per cent. showed infection with *Rickettsia orientalis*. *Rattus rattus* was the chief reservoir of infection.

A suitable method for breeding *T. deliensis* in the laboratory was evolved and mites had been bred through several generations. The life history of the mite has been fully worked out.

Using larval mites (*T. deliensis*) bred out from larvae collected from the ears of rats trapped in Barrackpore area, transmission experiments were conducted. It has been shown that *T. deliensis* was

the vector in this area and that transovarian transmission of the infection occurred in the mite over at least four generations.

In all eleven species of mites were discovered and on the basis of a detailed study of their characters, a synoptic table for identification of the larval stage was prepared.

From the studies conducted it appears that probably only *T. deliensis* was concerned in transmission of scrub typhus in this area.

Koenigsfeld (1945) reported 67 cases from troops on jungle training in swampy and scrub areas at a centre in the foot-hills of Nilgiris during September to November 1944. Thirty-three of these cases were positive to OXK. One case which was complicated with malaria and amoebic dysentery proved fatal. In the Maldive Islands, scrub typhus appeared to be endemic. Wedd (1944a) and Hay (1944) of the hospital ship *Vita* reported 79 cases with one death, from the Maldive Islands and Diego Garcia in Chagos Archipelago, occurring in ships and naval establishments from the middle of 1941 to the beginning of 1943.

Bindra (1944) reported typhus with rising OXK titre from Addu Atoll in the Maldives during the period May to December 1943. Fifty per cent. of men from auxiliary pioneers and anti-malaria units, in whom contact with scrub could be traced, were affected. In a field battery which embarked on clearing the area surrounding the camp 40 per cent. of the men were affected within six weeks. In the troops at Addu the total number of cases among IORs during 1942 and 1943 were 1,056 with 24 deaths. Twenty-one BORs were affected during the same period with no deaths. The fatality rate was 2 to 5 per cent. in the undernourished IORs. The peak case incidence occurred in August 1942, when the rate was 49·5 per 1,000. This was followed by a second peak in December with a case incidence of 35·7 per 1,000.

But the most remarkable explosive outbreak of scrub typhus occurred in December 1943, among troops of the 11th East African Division, who were on a training manoeuvre for five days in the Embilipitiya area of south east Ceylon. By 14 January 1944, the number of cases in hospital totalled 756. Of these 43 were British and 713 Africans. The mortality rate was 1·3 per cent. among the African troops but there were no deaths among the British troops. The terrain consisted of extensive *chena* cultivation on both sides of a road as a result of which high jungles were replaced by low jungles mixed with scrub with which the troops had intimate contact during their exercise. The local inhabitants usually did not have such contact. The actual ground covered lay partly along the Hambantota-Ratnapura Road, from Embilipitiya (Mile 103 on Madmpe-Ambalantota Road) to the neighbourhood of the river and village Timbolketiya (at mile 95) and also penetrating deeply in the surrounding jungles in the regions of Walawe Ganga and Rakwana Ganga.

Before this outbreak scrub typhus had been reported in Ceylon only occasionally. Out of 434 sera tested in 1937, only six were positive

to OXK. In 1938, Wijerama had reported two OXK positive cases. A European who was on a hunting trip in 1940, in the Arugam Bay on south east coast got an attack (Nicholls, 1940). In 1943, 23 British and 16 Indian soldiers were affected in the coastal areas. During the period 1944-46 there were ten cases among Indian troops and three among the Ceylonese troops. British and African cases during this period numbered three and six respectively in addition to the epidemic which occurred amongst them in January 1944.

INDO-BURMA BORDER

Central Front : Sporadic cases from widely scattered areas around Imphal were admitted during the first eight months of 1943. Tattersall and Parry (1945) have reported 121 cases of OXK typhus amongst troops of two companies of a British battalion which patrolled a certain hill feature near Tamu, later known as Mite Hill, during October and November 1943.

More than 300 cases admitted into medical units of the IV Indian Corps, occurred in the Fourteenth Army (Taylor, 1944) during the period September to December 1943. The mortality rate was 6·9 per cent.

As military operations of considerable magnitude began to take place in 1944, specially during the later months when troops moved into Kabaw Valley, and then into Northern Burma across the Chindwin, the incidence of scrub typhus increased simultaneously and ranked only next to malaria as the most serious medical problem of the Eastern Army and the Fourteenth Army. The total number of cases recorded in 1944 was 5,000 with some 350 deaths (Sayers and Hill, 1948). The highest case incidence was in August when more than 800 cases occurred and this continued for the rest of the year at the rate of 600 to 700 cases per month.

Fielding has reported on the occurrence of scrub typhus in XXXIII Indian Corps during the period July 1944 to May 1945. There was a total of 2,399 cases of scrub typhus with a mortality rate of 10·04 per cent. The overall fatality rate in the SEAC was 10 per cent. Scrub typhus accounted for 3·3 per cent. of all sickness and 2·92 per cent. of all admissions in the Corps. On an average one out of every 150 of the fighting troops was down with scrub typhus. The areas chiefly affected were routes leading out of Imphal plain, Kabaw Valley, regions of Fort White, Kennedy Peak, Kalemyo, Sagaing, Mandalay and Prome.

The 11th East African Division held a record for incidence of scrub typhus. Besides 756 cases in Ceylon, they had 900 cases during the monsoon campaign down the notorious Kabaw Valley. A battalion of the 2nd West Yorks had 18 per cent. of the strength down with scrub typhus and 5 per cent. dead during a period of two months while operating along the Tiddim Road.

During the period July to September 1945, seventy-nine cases of scrub typhus were reported from the Kabaw Valley at mile-stone

MAP SHOWING AREAS IN BENGAL, ASSAM & BURMA WHERE SCRUB TYPHUS WAS REPORTED IN 1944-45

SCALE OF MILES

0 50 100 150 200

SCRUB TYPHUS ---

24 and milestones 90-96 on the Moreh-Kalewa Road, in the Kyigon Gorge and on the banks of Myittha River.

Southern Front (*The Arakan*) : Early and Templeton (1945) reported that scrub typhus that occurred in the coastal strips of East Bengal, north of the Arakan Yomas and in places like Chittagong, Chiruga, Dohazari, Cox's Bazaar and Dhoapalong, was very mild in type with no fatality. In 1944-45, 45 cases were reported, 19 of which proved to be cases of scrub typhus.

In November 1944, when operations spread into the Kaladan Valley, approximately 100 cases were reported from the West African troops.

Northern Front : Scrub typhus was reported in May 1944, from the 3rd Indian Division (Special Force) operating in North Burma. Fifty cases were flown to the hospitals in North Assam of whom fifteen died. Between May and September 1944, a total of 132 cases were reported from this Force, (Sayers and Hill, 1948) the infective foci being in the hills south and south east of Lake Indawgyi. Eleven cases occurred among units of the Fort Hertz garrison camping on Myitkyina—Fort Hertz Road. The British division which replaced the Special Force and operated down the 'railway corridor' towards Sahmaw had a total incidence of 282 cases, majority occurring in the last two months of the year, but the mortality rate, which was 2·6 per cent., was very low in comparison with Special Force.

The disease also proved a serious medical problem to the Chinese troops undergoing training in the vicinity of Ledo (Assam), and to the Merrill's Marauders in their campaign through the wet Hukawng Valley to Myitkyina. At first termed 'CBI' fever, it was shortly recognised to be scrub typhus or *tsutsugamushi* disease (Pepper, 1944). Mackie, executive officer of the USA Typhus Commission set up at Myitkyina in October 1944, has observed that a total of 1,098 cases of scrub typhus occurred among the United States and Chinese troops from 1 November 1943 to 1 September 1945. The overall fatality rate was 8·9 per cent. It occurred in the vicinity of Ledo and in camps along the Stilwell Road. The main endemic foci were the regions immediately east of Ledo, the vicinity of Shingbwiyang, the mountainous region east of Shaduzup, the Myitkyina area, the country about Mogaung and the areas to the south and east of Namkham.

A distinguishing feature regarding the epidemiology of the disease was that an overwhelmingly large majority of cases occurred among men engaged in combat or combat training as contrasted with the non-combat personnel among whom the incidence was negligible though they formed the bulk of the advance section of the troops.

BURMA

When Burma was overrun, scrub typhus was reported from various areas, in the urban or suburban waste lands, in *ponzos* (abandoned sites after *taungya* or shifting cultivation), in foot-hill camps, in road-side scrub, in jungle fringes of stream-beds and valleys and in or on the outskirts

of many villages in the rich rice growing areas of the Irrawaddy delta. About 600 cases occurred in Burma between June and December 1945.

In May 1945, and in the following months 28 cases were reported from Fort Dufferin in Mandalay. All the cases had been billetted near the south gate in the neighbourhood of a moat. One Indian regiment had about 60 cases as the result of a ten day training march from Mandalay to Meiktila.

Nine cases were reported from Sagaing in a unit housed on the banks of the Irrawaddy, the compound of which was overgrown with sparse grass and herbaceous weed two to three feet high.

On the Thazi-Kalaw Road five cases occurred in the 99th Brigade during their advance to Kalaw in May 1945. Cases occurred in the hills above Thazi, mostly in Kalaw area and also in the hills in Maymyo area. There was an outbreak of 16 cases between milestones 18-23 on the Maymyo Road in a labour corps. It is interesting to observe that in 1940 there were some ten to twelve cases of typhus amongst British troops in this area.

In 1945, there were 30 cases in Meiktila and its environs and 15 cases at Myingyan on the Irrawaddy.

On the Toungoo-Mawchi Road, three cases were reported from gardens flanking the road embankment between milestones 1 and 2. Cases also occurred in the foot-hill section of the road and at several road-side camps such as at milestones 15-17, (at least six cases) 19-20, 26, 36, 46 and 70.

At Mawchi seven men in a company of East African unit were affected while clearing waist high grass and wild Mexican marigolds around neglected and filthy living quarters. Four cases occurred in another company, infected north of Kemapyu, either while clearing a camp-site of waist high grassy scrub or in destroying Japanese dumps in the bushes off the road.

Over 47 cases were reported along the Toungoo-Rangoon Road, thirteen of these being from Toungoo area. In Rangoon itself cases of scrub typhus occurred and like Calcutta it was not free from endemic foci within the town limits. Cases had been recorded from Insein, from the neighbourhoood of Mingaladon airfield and from Hlegu. Prome was one of the worst centres of infection. Several outbreaks occurred and the total incidence of 62 cases was the highest of any area in lower Burma. Cases were recorded from Taikkyi, Letpadan, Minhla, Tharrawaddy and Paungde, on the Prome-Rangoon Road. Several cases were reported from troops of the 17th Indian Division patrolling in the foot-hills of the Pegu Yomas, and from Tambingon.

In the 82nd West African Division, 22 OXK positive and 15 clinical cases were seen during November and December 1945. One was British and the rest African other ranks of whom two died. Majority of the cases occurred at milestones 33, 47½ and 70 on the Taungup-Prome Road except one case which was imported from Bassein.

Table V gives the incidence of typhus in the SEAC during 1942-45.

TABLE V

Incidence of typhus fever on Indo-Burma front and SEAC (less Ceylon)—1942-45.

Categories of troops	1942		1943		1944		1945 (January to September)	
	Actual	Rate per 1,000	Actual	Rate per 1,000	Actual	Rate per 1,000	Actual	Rate per 1,000
VCOs and IORs	32	0·3	289	1·0	673	2·1	342	1·11
NCs(E)	...	...	66	0·6	83	0·8	64	0·65
Total Indian troops	32	0·22	355	0·95	756	1·77	406	1·00
British officers	...	...	32	2·85	45	2·80	11	0·62
BORs ...	32	0·7	80	1·4	437	5·54	68	0·97
Military Nursing Service (British)	...	...	1	3·1	...	...	...	...
Total British troops	32	0·64	113	1·63	482	5·15	79	0·90
West African other ranks ...	...	...	...	...	23	0·61	4	0·10
East African other ranks ...	...	...	...	...	233	10·26	39	1·87
All Forces	64	0·33	468	1·05	1494	2·87	528	0·95

CLINICAL FEATURES OF SCRUB TYPHUS

Many observers have recorded the clinical features in the SEAC as well as in the South West Pacific. These have been remarkably uniform except for variations in primary eschar, rash and adenopathy. Tattersal (1945) analysed 1,000 cases from the Indo-Burma border. The onset was sudden in most of his cases and in 11 per cent. a primary ulcer was seen associated with regional lymphadenitis. The rash which was macular or papular, occasionally purpuric, appeared in 31 per cent. of Indian troops and 64 per cent. of British troops. Discrete generalised and tender enlargement of lymph glands appeared in 92 per cent. of cases on the third day and disappeared by fifteenth day. Cough was present in 100 per cent. of cases and patchy basal consolidation was commonly detected. Mental changes were also seen in 100 per cent. of cases ranging from blunting of intellect to coma or mania. Splenomegaly was seen in 47 per cent. of cases during the third to fourth week. Deafness appeared in 35 per cent. of cases but improved during convalescence.

Flushing and cyanosis were noted on the fourth day in 100 per cent. of British troops. Headache, frontal and retro-orbital, was seen in all cases and relief sometimes followed lumbar puncture. A secondary fever varying from three to five days was seen in 15 per cent. of cases after remission. Leucocyte count was substantially normal and agglutination reactions to *Proteus* OXK, in 500 cases in which the test was carried out, was 1 in 200 or over in 80 per cent. between the eleventh and thirteenth day. Complication such as lobar pneumonia, pleural effusion, lung abscess or empyema occurred in 10 per cent. of cases. The other complications were haemorrhages in 9 per cent. of cases, subconjunctival, epistaxis, haemoptysis, haematemesis, venous thrombosis and symmetrical gangrene in two cases each ; nervous sequelae in 2 per cent. of cases which included retrobulbar neuritis and fleeting painful paralysis of muscles of the shoulder girdle. Patients bore a journey badly after the fifth day. Convalescence was prolonged and sometimes cardiac neurosis developed as a result of solicitous attention paid to the cardiac condition. The fatality rate in these groups of cases was 6 per cent.

Amongst the 121 cases from the British regiment affected on Mite Hill, Tattersall and Parry (1945) noted that frontal headache with photophobia was present in 100 per cent., sore throat in 63 per cent. and conjunctival injection in 59 per cent. of cases. The differential count showed 46 per cent. lymphocytes on an average and eosinophilia was seen between fourth and fifth weeks. Poor response to exercise tolerance test was seen for three to four weeks during convalescence. On analysing 200 cases among East African troops from the Burma front, Deshmukh (1945) observed eschar in 35 cases and found that generalised lymphadenitis and pains in the bones and joints were usual. Inconspicuous macular rash was seen in fifteen persons and eight developed insanity. Widespread neuritis, viz., auditory, facial, laryngeal, optic and in nerves of the legs and arms, was observed. Phlebitis of femoral veins and suppurative parotitis were occasional complications. In the large number of cases seen among troops of XXXIII Indian Corps, the symptoms noted in order of frequency were headache, conjunctival injection, rash varying from scattered papular to generalised morbilliform eruption, cough, apathy, chills and rigors, body aches, enlarged spleen, enlarged liver, sore throat and meningisms. Cyanosis with a bloated appearance were frequent among the British troops.

Bindra (1944) has reported that in the cases seen at Addu Atoll, the fever lasted thirteen to fourteen days and reached normal by rapid lysis in two days. Other symptoms seen were intense headache, drowsiness, congested eyes, slow pulse, furred tongue, rigidity of neck, rash, enlarged lymph glands, palpable spleen and a rising OXK titre. Lymphocytosis was seen in 40 to 50 per cent. of cases. In the Ceylon outbreak primary eschar was seen in the folds of neck, chest, back, flanks, groins, thighs and genitals. Complications such as albuminuria, axillary abscess, parotitis, haematuria, bronchitis and bronchopneumonia occurred. Infarct of spleen was seen which went on to abscess formation.

Walker (1944) reporting on the Calcutta cases, observed that in 1942, high continued fever of sudden and severe onset came to normal by crisis on the fourteenth day and a short period of convalescence followed, but in later cases, a prolonged fever subsiding by lysis covering a period of one week and a long period of convalescence was observed. The disease simulated malaria, cerebrospinal fever, enteric group of fevers, small pox and severe dengue. Differential diagnosis was sometimes difficult. The usual symptoms were headache, cough, generalised body ache, photophobia and a state of drowsy resistance. Generalised and tender enlargement of lymph glands and enlargement of spleen were observed but there was no eschar. Dark red papules, about ($\frac{1}{2}$ cm.) in diameter, superimposed on mottled skin mostly on the trunk but less on periphery appeared between the third and tenth day. Retention of urine was noted and changes in the myocardium were reflected by a rising pulse rate, short and high pitched first sound, tic tac rhythm and extra-systoles or auricular fibrillation. But it is the view of many observers, that permanent cardiac disability does not occur in scrub typhus. Williams, Sinclair and Jackson (1944) did not find any evidence of permanent cardiac disability in those who recovered. Berry, Johnson and Warshauer (1945) found no myocardial damage on electrocardiographic examinations in 30 cases. Howell (1945) did not find any change on electrocardiographic study of 200 consecutive convalescents from scrub typhus. In a series of 100 cases in which electrocardiogram was done, significant changes like bundle branch block or intraventricular block were seen in three cases by Likoff (1946). Levine (1945) has pointed out that suggestion of heart disease may make an almost ineradicable impression on the minds of people suffering from scrub typhus and may lead to neurocirculatory asthenia. In this series of 130 cases, only two were true cardiac disease as revealed by electrocardiogram and X-ray examination, though during early convalescence, dyspnoea, palpitation, tachycardia, hypotension and effort syndrome were common. Romeo (1946) has also emphasised that apprehensions for incapacitation should be removed. In a series of 312 convalescents examined,only 8 per cent. needed temporary bed treatment.

Krishnan, *et al.* (1949) published the results of their investigations on scrub typhus in the Barrackpore area. The clinical, epidemiological and transmission aspects of the disease were studied. Clinically the cases could be divided into two types—mild and severe. About 80 per cent. of cases were of the mild type and the rest were of the severe type. Diagnosis of mild cases was not possible by clinical examination alone. Laboratory aid had to be sought for establishing diagnosis in the majority of these cases. All the severe cases showed the characteristic symptoms such as intense headache, congestion of eyes, rash, mental dullness, sleeplessness etc., and these could be diagnosed on clinical grounds. In all cases diagnosis was confirmed by laboratory findings.

In the North-East Burma 110 cases were noted by Menon and Ibbotson (1945). Besides the usual symptoms, 56 per cent. showed an eschar, and a rash, maculopapular or macular, were seen in 64 per cent. of cases on the trunk, thighs, upper arms or face, appearing between

the fifth and sixth day. Mental changes like apathy, confusion, restlessness, delirium or a 'typhoid state' were seen in 50 per cent. of cases. Co-existing malaria was very common and a therapeutic course of mepacrine was given in all cases at onset. Other unusual symptoms were a sudden diuresis occurring between the tenth and sixteenth day of disease as observed by Andrew (1945) for which no obvious cause could be found. It was a warning against deranging the fluid balance by excessive intravenous administration. It was observed in a bulletin from the War Office (1944) that fluid retention occurred in the early stages of scrub typhus but oedema became masked due to loss of flesh. This was followed by diuresis on the fourteenth day associated with clinical improvement but a deceptive appearance supervened as the oedema was removed and full extent of wasting revealed. Hence intake and output of fluid should be carefully balanced and ill-advised intravenous administration may have special dangers.

Donegan (1946) observed that a vascular upset in the eyes in the form of hyperaemia of conjunctiva and fundus occurred in scrub typhus but neural or neuroglial cells were not involved. Dame (1945) has reported that in 50 convalescent scrub typhus cases, 50 per cent. had noticeable transitory eye symptoms such as enlargement of blind spots, contraction of visual fields and scotomata ; 78 per cent. of the cases had loss of hearing or tinnitus ; but during convalescence, only 11 per cent. had minor non-specific involvement of the cochlear system. In 59 per cent. of cases, involvement of vestibular system was present.

Blood Picture: Total white cell count did not give much information but lymphocytosis was a common feature. Wedd (1944b) has noted increase of azurophilic granules in lymphocytes termed as speckled lymphocytes but Megaw prefers to call it azurophilosis. O'Connor (1945) has observed that Hirst's haemagglutination phenomenon is exhibited by *R. orientalis*. Gottfried (1945) studied the blood chemistry in 47 patients of scrub typhus. Blood urea nitrogen was high in one fatal case. Low serum proteins were usual in soldiers back from combat areas due to exhaustion and malnutrition. But a rise was observed during fever due to increase of globulin as a protective response. Low serum albumin was seen in early convalescence. Plasma fibrinogen was low in patients as well as in controls. Liver function and serum calcium were low.

PATHOLOGY

Tattersall and Parry (1945) reported from a series of eleven post-mortem examinations that congestion of meninges and of the brain surface and enlargement of the mesenteric lymph glands occurred in all. Extreme pulmonary congestion and dilatation of the right side of heart were seen in ten and pneumonia in six cases. Petechial haemorrhages occurred in stomach, ileum, caecum and colon in five cases. Deshmukh (1945) noted congested lungs and kidneys, enlarged, soft and friable spleen, congestion of the superficial vessels of the brain, enlarged mesenteric glands and pin-pointed haemorrhages in the stomach

and intestine. On microscopical examination endothelial swelling and proliferation of the capillaries of brain and endothelial proliferation in the lymph glands were noted. Cells of the renal tubules were swollen and necrosed. In the fatal cases of Ceylon outbreak, congestion of the larynx, trachea and lobar or bronchopneumonia occurred. Regional lymph glands were enlarged and mesenteric and para-aortic glands were discrete and rubbery. Marked increase in the interstitial tissue of kidney occurred and early subcapsular scarring were seen. Spleen was sometimes soft and septic and liver showed occasionally fatty change. Rickettsiae were seen in the biopsy material from axillary group of lymph glands. McGovern (1945) noted that the chief histological change was a vasculitis and other changes such as myocarditis, pneumonitis or pneumonia and meningo-encephalitis were secondary to it. Periadventitial collection of round cells and mononuclear infiltration of intima of large vessels like the coronary were seen.

Settle, Pinkerton and Corbett (1945) observed that essential pathological lesions in *tsutsugamushi* disease were direct results of multiplication of rickettsiae in endothelial cells or smooth muscle cells of blood vessels. The organisms caused swelling and proliferation of endothelium, cellular infiltration of vessel walls, perivascular infiltration of mononuclear cells and occasionally thrombosis and haemorrhage. There was a frequent occurrence of local ulcer and great involvement of serous membranes, myocardium, lungs and lymph nodes. Generalised vasculitis sometimes caused peripheral circulatory collapse and death. Allen and Spitz (1945) concluded that arteritis was exceedingly slight in scrub typhus in contrast with epidemic typhus and Rocky Mountain spotted fever. The typhus nodules in brain were similar in type in scrub typhus and epidemic typhus but a different picture was seen in Rocky Mountain spotted fever where microinfarcts were distributed in the white matter of brain. Mendell (1946) observed that vasculitis and perivasculitis in the small vessels of brain, lungs and heart were the chief feature of scrub typhus. Reticuloendothelial system was mainly affected and there was a pronounced tendency to haemorrhage. Hicks (1945) observed that the chief histological changes were proliferation of the reticuloendothelial tissues and infiltration of interstitial tissues with mononuclear cells, specially in the heart, lungs and spleen. Capillary endothelium was swollen throughout the body. Frequent small haemorrhages were seen in the pons and midbrain. Berry *et al.* (1945) noted vascular changes such as perivascular cellular infiltration and degenerative changes in the vascular endothelium of arterioles and capillaries of various organs. de Vidas (1945) observed that the predominant lesion was perivascular infiltration with lymphocytes and histiocytes. But in two specimens vasculitis and endothelial proliferation were seen with thrombosis and haemorrhage. Levine (1945) noted widespread perivascular infiltration of lymphocytes and plasma cells but in contrast to other workers he did not observe any tendency towards thrombosis or haemorrhages as in some other rickettsial diseases. Kouwenaar (1940) noted that the chief change in scrub typhus was a perivascular infiltration only secondarily attacking the intima whilst

in the classical and endemic forms, the primary lesion was destruction of intima and media followed by perivascular infiltration.

Macdonald (1944) has compared the lesions in fatal cases of scrub typhus from the Burma-Assam border with those of louse-borne typhus. In the skin there is no intravascular lesion but only hyperaemia and perivascular round cell infiltration in mite typhus, whereas severe lesions of vascular endothelium followed by thrombosis and development of typical perivascular cellular nodules occur in louse typhus. In spleen and lymph nodes, intense hyperaemia and oedema with infiltration of the reticulum and sinuses by mononuclear cells occur in both but in addition to these, intravascular lesions are seen in louse typhus. In liver, degenerative changes in the liver cells with biliary stasis and mild round cells infiltration of portal tracts occur in both. But in mite typhus, changes in the Kupffer's cells are slight, whereas they are very severe in louse typhus. In kidney a mild and in many cases a severe degree of acute interstitial nephritis with no obvious glomerular lesions occur in mite typhus but a true intracapillary glomerulitis may be present in louse typhus. A constant underlying lesion in the lungs, often obscured by secondary pneumonia, oedema and round cell infiltration of peribronchial and perivascular tissue, is present in mite typhus but in louse typhus this is absent. Well marked acute interstitial myocarditis occur in a proportion of cases in both but in the early cases of louse typhus vascular lesions similar to those of the skin occur. Acute inflammation of the interstitial connective tissue of gastrointestinal tract is seen in mite typhus but no such lesion is seen in louse typhus and vascular changes are absent. In brain intense hyperaemia without typical encephalitis occur in mite typhus, whereas severe and pathognomonic vascular lesion occur in louse typhus.

Macdonald also succeeded in demonstrating the rickettsiae of scrub typhus in the endothelial cells of the precapillaries of brain from a fatal case.

SEROLOGICAL OBSERVATIONS

Weil-Felix Reaction : Majority of the cases seen in the SEAC developed agglutinins to *Proteus* OXK suspension, sometime during the course of the disease. A significant titre may not be reached till after defervescence and on this account to determine the diagnosis, Weil-Felix test should be performed at weekly intervals for four to five weeks (Bardhan, 1944). In the laboratories of the Fourteenth Army in 1944, 91 per cent. of sera from 2,919 cases of typhus were reported as agglutinating OXK in preponderance. The remaining cases showed a predominant titre against OX19 in 3 per cent., against OX2 in 2 per cent. and a mixed agglutinin response to two or more suspensions in 4 per cent. (Sayers and Hill, 1948). Seaton and Stoker (1946) of the GHQ Base Typhus research team, Poona, made a serological analysis of typhus cases in India. They observed that scrub typhus cases could easily be recognised by their isolated high titre to *Proteus* OXK and hence were not further examined. Sera from 216 patients were analysed and of these 69 cases showed an isolated response to OXK suspension

in high titre. The remaining 147 sera were tested both by Weil-Felix reaction and rickettsial agglutination test, using epidemic and murine rickettsiae as antigens. Agglutinin response to murine rickettsiae was predominant in most cases. But no absolute distinction could be drawn by this test between murine typhus and tick typhus though usually a higher titre was obtained in the former case. Similarly it was shown that while in general murine typhus sera agglutinated *Proteus* OX19 to a higher titre than *Proteus* OX2, and the reverse obtained in tick typhus, the Weil-Felix reaction did not afford an absolute means of distinguishing between these diseases.

Phease (1944) of the Central Military Pathology Laboratory also observed on the serological classification of the typhus group of fevers in India. In the types met with in Simla hills, Northern India and Assam, definite, unequivocal and high titres against OXK, with the total exclusion of co-agglutinins for OX19 and OX2 were almost invariably met with. The second type usually confined to South India, reacted chiefly but by no means exclusively with the OX2 antigen, but the titres never rose to the height met in the OXK type. Clinically, the severity of the disease and widespread distribution of rash suggested that it was related to the Rocky Mountain spotted fever group. The third serological type was that which reacted most strongly with OX19 antigen but the diversity of serological reactions as well as clinical picture suggested that more than one species of rickettsiae were involved in it.

Rickettsial Agglutination Test : Eyer, Przybylkiewicz and Dillenberg (1940) found that serum agglutination test with suspensions of rickettsiae were more specific than Weil-Felix reaction.

Fitzpatrick and Hampil (1941) recorded experiments in rabbits which suggested that rickettsial agglutinins appeared earlier and were more specific than the Weil-Felix response. Hudson (1940) used emulsions of rickettsiae from lungs of infected rats and mice as antigens. Van Rooyen and Bearcroft (1943) found from a series of cases of epidemic and murine typhus in the Middle East that, with the rickettsial agglutination test, some epidemic cases were agglutinated with the corresponding rickettsiae in a far higher titre than the murine and vice versa. Kligler and Olejnik (1943) also found that rickettsial agglutination test could effectively differentiate murine from epidemic typhus. Castaneda (1945) used rickettsia agglutination slide test and found that agglutination to the homologous organism occurred at a much higher titre than the heterologous organism. Nevertheless, cross-agglutination occurred, especially with antimurine serum and epidemic rickettsiae. Castaneda and Silva (1941) further concluded from cross-immunity experiments in guinea-pigs that there was definite immunological overlapping between Rocky Mountain spotted fever and epidemic and murine typhus. Animals which had recovered from the latter infections showed a high degree of resistance to Rocky Mountain spotted fever infection. Sera from patients with the spotted fever were found to agglutinate both *Proteus* OX19 and *R. prowazeki*. Fitzpatrick (1945) reported that rickettsia agglutination test could differentiate fevers of the Rocky Mountain spotted fever group in a clear-cut manner. Epidemic and

murine typhus could be distinguished by a difference in titre of the reaction to the respective antigens. Van Rooyen, Danskin, Pollack and Bearcroft (1944) from a study of rickettsial agglutination test concluded that the epidemic strains were more common in Egypt, Iraq and Iran, whereas murine strains were common in Palestine. Van Rooyen, Bowie and Krikorian (1944) observed that best results were obtained with the rickettsia agglutination test from the tenth to the fifteenth day of the disease but that the antigen was more costly. Eight sera from typical cases at Imphal were submitted for examination to Van Rooyen at the Central Military Pathology Laboratory, Middle East Force and to the Army Emergency Vaccine Laboratory in the United Kingdom. Louse-borne and flea-borne strains were used but unfortunately it was not possible to prepare suspensions of *R. tsutsugamushi* for the agglutination test. As only traces of agglutination in low dilution against epidemic or murine rickettsiae were seen, it was concluded in a report of the Army Emergency Vaccine Laboratory in 1944, that the results did not suggest any antigenic relationship between the OX19 and OXK groups of typhus.

Complement Fixation Test : Bengtson and Topping (1942) found that complement fixation test with a rickettsial antigen was of considerable value and superior to Weil-Felix reaction in differentiating endemic typhus of the USA (murine) from the Rocky Mountain spotted fever. Bengtson (1941) observed that complement fixation test with murine rickettsiae from lungs of infected mice or yolk sac of developing chick embryo could detect cases of endemic typhus as old as nine years and as recent as a week. Reynolds and Pollard (1943) observed that epidemic typhus vaccine of the Cox's type was an effective antigen for complement fixation reaction in order to differentiate the rickettsial diseases. Plotz (1943) was able to differentiate epidemic from murine typhus by the complement fixation technique. Cross fixation occurred in a minority of cases but at much lower titres than with the homologous antigen. Plotz, Wertman and Reagan (1944) have emphasised the help given by the use of complement fixation reaction in differentiating fevers of the typhus group. Plotz, Bennett, Wertman and Snyder (1944) tested sera of persons suffering from Rocky Mountain spotted fever by the Weil-Felix reaction, rickettsial agglutination test, complement fixation reaction and mouse-neutralising test. They concluded that only the complement fixation reaction could differentiate Rocky Mountain spotted fever from epidemic and murine typhus. Brigham and Bengtson (1945) produced experimental evidence to show that complement fixation test was much more sensitive to detect the occurrence of typhus in rats than the Weil-Felix reaction. Wertman (1945) observed that relatively crude egg yolk suspension may contain non-specific antigens likely to give false positive reactions. These should be removed by repeated washing and centrifugation before performing the test. Damon and Johnson (1945) advocated the use of fresh rickettsiae when testing for murine typhus. Plotz and Wertman (1945) noted that though complement fixation test and rickettsial agglutination gave consistent results in the unvaccinated, anomalous response were obtained in the vaccinated persons. Plotz, Wertman and Bennett (1946) showed that

complement fixation test was a more reliable indication than febrile or scrotal reactions in the differential diagnosis of guinea-pigs infected with rickettsial strains. Though epidemic and murine strains gave some degree of cross-fixation, yet the response with the homologous antigen was four times or more higher in titre. Bengtson (1945a) concluded that complement fixation test in rickettsial diseases was highly specific and likely to become a procedure complementary to Weil-Felix reaction. It could also be used for retrospective diagnosis in rats.

Bengtson (1945b) found that complement fixing titres in animals infected with different strains of *R. tsutsugamushi* were higher when tested with the homologous strain, suggesting apparent serological heterogeneity among strains of *R. tsutsugamushi.* But Topping (1945a) observed cross-immunity in guinea-pigs for four different strains of *R. orientalis* from Malaya, Assam, Burma and New Guinea. Malayan strain was most virulent and one of the strains from New Guinea was least virulent. Sera from different theatres of war were fixed by both the Karp (New Guinea) and Gilliam (Assam-Burma) antigens. Three sera from cases in Imphal were examined by Topping at the National Institute of Health, Bethesda, with the various types of typhus antigens. All the three sera fixed complement to high titre (1 in 256, 1 in 512 and 1 in 2,048) with the ' Karp ' strain of scrub typhus from New Guinea showing close immunological relationship of the disease in the two areas. Negative results were obtained with all other typhus antigens.

Seaton and Stoker (1946) of the GHQ Base Typhus Research Team, Poona, examined 40 sera which agglutinated murine rickettsiae and either or both *Proteus* OX19 and OX2. By the complement fixation technique eighteen cases fixed complement, in the presence of murine rickettsiae with no cross-fixation, sixteen did so in the presence of Rocky Mountain spotted fever antigen with cross fixation in one case only and that to a much lower titre, while of the remaining six sera, five were negative with both antigens and the sixth was positive with both to a titre of 1 in 5.

The incidence of murine typhus among wild rodents in Poona and Bombay was assessed by Stoker by the complement fixation technique with the murine rickettsial antigen. Evidence of previous infection was found in 9·5 per cent. of 338 rats and 7·1 per cent. of 42 bandicoots from Poona and in 9.3 per cent. of 75 rats from Bombay. Rickettsial infection was confirmed by the isolation of two strains from pooled brains of rats and bandicoots respectively and a further strain from rat-fleas. Previous infection with the bandicoot strain completely protected a guinea-pig against the flea strain.

ANIMAL EXPERIMENTS

Attempts to transmit the infective agent of scrub typhus to experimental animals by injecting fresh blood or pooled ground clot from local cases intraperitoneally into guinea-pigs, were made by Parker at the District Laboratory, Calcutta, in October 1943. Guinea-pigs injected intraperitoneally with fresh blood or pooled ground clot from

several cases of scrub typhus at Imphal, India-Burma border and North Burma were sent to the base laboratory. It was concluded that this method of inoculation into guinea-pigs and producing an 'inapparent infection' was useful where infective material had to be conveyed over long distances. Parker working in collaboration with Savoor was successful in isolating four strains of rickettsiae following the technique of Lewthwaite and Savoor (1936); one was from Calcutta, two from Imphal and one from North Burma. Three of these strains were studied by serial passages in rabbits. When infective material or infected human blood was injected into the anterior chamber of the rabbit's eye, a typical reaction followed, consisting of circumcorneal injection, intense iridocyclitis and a subsequent corneal haziness. Intraperitoneal injection of infective material into mouse proved fatal at about the thirteenth day. Rickettsiae were regularly present in large numbers, after the first one or two serial passages, in the profuse white peritoneal exudate. Since the infective agent demonstrated, bore a close resemblance to *R. tsutsugamushi*, it was concluded that the disease occurring in Bengal and Assam which gave a positive OXK titre, were in fact, cases of scrub typhus or *tsutsugamushi* disease.

In Ceylon, Lucas (1944) isolated a strain of *R. tsutsugamushi* from man by passage through guinea-pigs, white rats and white mice. He considered white mouse to be the animal of choice. Savoor (1944-45) working at the Haffkine Institute, Bombay isolated three strains of XK typhus and identified two more isolated in military laboratories as XK typhus in 1944. He also confirmed the findings of Dutch workers that for cultivation of *R. tsutsugamushi* in duck eggs, a small inoculum and a long incubation period of seven days at 36° C. was necessary. An orchitic strain was isolated and cross-immunity experiments with 'Wilmington' strain proved that it was milder. In 1945, Savoor at the same institute isolated two orchitic strains in guinea-pigs and three strains of *R. tsutsugamushi* in mice. Complete reciprocal cross-immunity was found between Bombay (Naigaum), Calcutta and Ceylon strains of scrub typhus. Van Rooyen and Danskin (1944) transmitted the Imphal strains to Egyptian rodents, using the gerbille and jeroba, thus demonstrating the susceptibility of these animals to *R. tsutsugamushi*. Zarafonetis (1945) also noted the susceptibility of gerbilles to strains of scrub typhus from Imphal, Calcutta and Ceylon. He concluded that this animal was a suitable substitute for white mice. Zarafonetis, Snyder and Murray (1946) observed that gerbilles infected with *R. orientalis* recovered from the infection with the help of para-aminobenzoic acid. The recovered animals were immune to reinfection with different strains of *R. orientalis*. Topping (1945b) noted that sera of immunised rabbits, injected subcutaneously, was found capable of preventing the death of mice challenged with lethal doses of *R. tsutsugamushi*. He considered *tsutsugamushi* diseases as specially favourable for serum treatment.

Weil-Felix test conducted by Krishnan *et al.* (1949) in Barrackpore area revealed that agglutination in high titres with OXK was not frequently obtained. In 90 per cent. of cases, the titre ranged from 1 in 125 to 1 in 250, and in only 10 per cent. it was over 1 in 500. Animal inoculation proved more useful in diagnosis. In cases in which

the agglutination titre was low or below the diagnostic level, animal inoculation proved useful. White mice were found to be very susceptible and inoculation of washed blood cells from typhus cases gave better results than crushed blood clot or whole blood. They recommended mouse inoculation for adoption as a routine measure for diagnosis.

TREATMENT

The mortality rate of scrub typhus in the SEAC was considerably reduced when troops were treated as far forward as possible instead of evacuating them to the hospitals in the rear areas. Scrub typhus cases were also unsuitable for air evacuation as multiple venous thrombosis developed in lungs and the lower limbs.

Treatment of actual cases was mainly symptomatic as no effective serological or chemotherapeutic treatment was then known. Fluid intake was maintained and intravenous saline given when necessary. Sometimes lumbar puncture was done to relieve symptoms of meningism (Bindra, 1944 ; Walker, 1944).

Yeomans, Snyder, Murray, Zarafonetis and Ecke (1944) reported encouraging results in a small series of typhus cases with para-aminobenzoic acid in adequately controlled experiments. Tierney (1946) observed strikingly good results in eighteen scrub typhus patients, nine Indian, eight Americans and one Chinese in the military hospitals at Ledo (Assam). Murray, Zarafonetis and Snyder (1945) noted that sodium salt of aminobenzoic acid given orally or subcutaneously greatly reduced the fatality rates in gerbilles inoculated with lethal doses of *R. orientalis*.

Andrewes, King, Van Den Ende and Walker (1944) reported that chemotherapeutic substances like V 147 and V 186 (p-sulphamide benzamide hydrochloride) were effective against rickettsiae and inhibited foci in infected mouse lungs. But clinical trial of these drugs proved disappointing.

Later reports indicate the efficacy of chloromycetin in reducing the incidence of scrub typhus. A United States Army Research Team (Dr. J. E. Smadel, Dr. T. E. Woodward, Lieutenant H. L. Ley, Colonel C. B. Philip, and Major R. Traub) and Dr. R. Lewthwaite and Dr. S. R. Savoor of the Institute for Medical Research, Kuala Lumpur, (Malaya), carried out investigations at the institute, on the curative properties of chloromycetin in the treatment of scrub typhus. The results were reported before the Fourth International Congress of Malaria and Tropical Medicine held at Washington, D.C., in February 1949. The drug appeared to provide an excellent means for treating the rickettsial diseases. The mould was first experimented upon by Dr. Paul R. Burkholder of Yale University, USA, who isolated an extract showing anti-bacterial properties. Later, the extract was obtained in crystalline form, and named chloromycetin, at the Research Laboratories of Parke Davies and Co. Detroit, Michigan. The investigations of Army Medical School, Washington D.C., showed that the protective properties of the drug extended to most of the rickettsial agents including *R. tsutsugamushi* and that its toxicity to animals, including man, was low.

In March 1948, the United States Army Research Team arrived in Malaya for human trial. Preliminary trials showed very satisfactory results in the treatment of scrub typhus with chloromycetin. Temperature became normal in two days, toxicity vanished and convalescence was well on the way. Thus, the successful results obtained in the laboratory were fully corroborated in human scrub typhus. The drug was given by mouth in tablet form and one day's administration sufficed in most cases. Though treatment is indicated as early as possible, yet successful results were obtained in cases treated as late as the eighth or ninth day.

PREVENTIVE MEASURES

Miticides, such as, DMP came into use at the end of 1942. McCulloch (1946) carried on extensive work in Australia. He found that the phthalates, though they poisoned mites, did not act as mite repellents since the mites freely traversed treated clothing until they were immobilised and finally died. DMP was more toxic but did not last long, while DBP was rather less toxic but stood up to exposure and was, therefore, more generally effective. An ounce of DBP rubbed into each set of uniform, kept them protective even after eight washings in soap and running water. DDT ceased to be protective after four washings, and DMP did not stand even three washings. Clothing could be effectively protected by smearing these with DBP every fortnight, using the palm of the hand. Protection of genitalia and eyes was necessary. Unused and unwashed treated clothing remained effective for two months and articles such as blankets required treatment every six months. Johnson and Wharton (1946) employed 10 per cent. DDT for disinfestation of soil and DMP or DBP for personal protection by smear method as well as for spraying the huts and tents. But later on, the United States forces in 1945 substituted benzyl benzoate for DMP (*J. Amer. med. Ass.*, 1945). Clothing which were impregnated by dipping in 5 per cent. benzyl benzoate in water withstood laundering and remained effective for two weeks. Bushland (1946) observed that garments impregnated with 5 per cent. DMP and 2 per cent. soap and water remained protective against *trombiculid* mites for five weeks unless they were laundered. To withstand laundering miticides, such as equal parts of benzyl benzoate and DMP, were advocated.

Other preventive measures consisted in treating the camp sites. Lewthwaite (1945) observed the use of flamethrowers for the purpose. Zair (1944) noted the use of bulldozers for scrub and jungle clearing in a naval hospital on Indian Ocean coast. The scrub was sprayed with kerosene oil and burnt before manual clearing. It was noted in a bulletin of the United States Army Medical Department (1944) that cutting and burning of long *Kunai* grass should be done by indigenous population since they possess immunity. This should be followed by burning the site with a powerful oil sprayer. For personal prophylaxis one should sleep above the floor level, in hammocks if necessary, and should bathe as soon as possible after being exposed to infection. Louge (1944) observed that besides the above measures, clothing should be removed after excursion and the whole body except genitalia lightly rubbed with cloth moistened with kerosene. Rat control should be on the same lines as in prevention of plague epidemic.

An enthusiastic rat campaign under field conditions was not found to be a suitable measure in checking scrub typhus for two reasons. Firstly, rats performed the very important task of 'mopping up' parasitic larvae from the ground and any disturbance of balance between hosts and larvae would lead to an increase of the scrub typhus risk. Secondly it was found that partially fed larvae when detached from their hosts would reattack any other available host such as man, to complete

their feed. In order to eliminate this risk, rats should be trapped alive and burnt without giving any chance to the larval mites to liberate themselves from their hosts.

As there was considerable apprehension among the troops regarding this disease, measures were taken to dispel the exaggerated fears by lectures and interviews. The dissemination of information on preventive measures was arranged by anti-malaria units. A cine-film on mite, its habitat and countermeasures, prepared under the technical direction of Dr. K. Mellanby, was widely shown.

VACCINE

Fulton and Joyner (1945) found that *R. tsutsugamushi* grew well in the lungs of cotton rats, *Sigmodon hispidus* and was suitable for vaccine production. Six cotton rats would produce 60 cc. of vaccine. In November 1944, an urgent request was received from the SEAC for one and a half million doses of cotton rat lung vaccine. Large quantities were prepared by the Wellcome Foundation for the Ministry of Supply, United Kingdom, and sent to the Headquarters ALFSEA. A great effort for preparation of protective vaccine was made by the National Institute for Medical Research (Medical Research Council, Report 1939-45). Buckland, Dudgeon, Edward and others (1945) have reported on the elaborate laboratory set up at Frant in Sussex on 31 May 1945, to meet the requirements of the far eastern war zone where scrub typhus was proving to be a great risk. By 30 October 1945, 300 litres of vaccine were prepared. Out of 60 workers employed in the laboratory three were attacked by the *tsutsugamushi* disease. Van Den Ende, Locket, Hargreaves, Niven and Lennhoff (1946) reported accidental laboratory infection in four persons while preparing cotton rat lung vaccine. Van Den Ende devised a special inoculation box in which all air leaving the chamber was sterilised by heat. Van Den Ende and Mills also devised a 'neutralisation' test for detecting and assaying the typhus antibodies. Discrete grey spots were seen in the lungs of infected mice which were reproducible for accurate quantitative work (spot-count technique). Smadel, Rights and Jackson (1946) suggested the use of white rats instead of cotton rats as they were easier to obtain and handle.

The first consignment of cotton rat lung vaccine arrived in New Delhi in November 1944, and was immediately given to selected units, with controls, which were at that time preparing to move forward from Imphal. Further field trials had been planned but it was not until July 1945, that it became possible to start these trials in troops of selected units in the Fourteenth Army owing to operational exigencies. The sudden cessation of the hostilities due to Japanese surrender, before the Fourteenth Army troops left India after re-organisation, made proper assessment of the efficacy of vaccine impossible. Card and Walker (1947) reported that available evidence suggested that the vaccine had no well-marked effect on the clinical course and serological reactions of scrub typhus. The number of cases were too few to judge the efficacy of vaccine by mortality rate figures in vaccinated and unvaccinated groups.

CLASSICAL TYPHUS—PERSIA AND IRAQ FORCE

In the winter of 1942-43, conditions were specially favourable for an epidemic of typhus in Persia (Sachs, 1946). The economic state of the poorer class was deplorable, the wheat crop was inadequate and starving ill-clad verminous population wandered from town to town and across the frontier to Iraq in search of food or occupation. The epidemic soon spread from the civilians and labourers to the many thousands of Indian and British troops stationed in Iraq and Persia. During the first seven months of 1943, there were 118 cases among Indian troops and 42 cases among British troops with an incidence ratio of 0·78 per 1,000. There were 35 deaths, 25 Indian and 10 British, the fatality rate being 21·2 per cent. in Indian troops and 23·8 per cent. in British troops. The overall fatality rate of 21·9 per cent. among Indian and British troops compares closely with the fatality rate of 22·75 per cent. among the same group of troops in the Mesopotamian Campaign of 1917-18.

The military cases were sporadic and reported from all parts of the command. In no instance, a case to case infection could be established and only three were louse-infested on admission to hospital. There was a total number of 2,036 cases among Persian civilians and 243 cases of labourers treated in the military hospitals in 1943, the mortality rate being 12 per cent. in the former group and 37·9 per cent. in the latter. The lower fatality rate among Persian civilians may be due to some degree of acquired immunity.

Preventive measures in the army consisted of segregation of contacts, disinfestation with the powder AL 63 containing naphthalene and derris root and provision of mobile bath and laundry units in dangerous areas. Special typhus teams provided with protective clothing, portable shower-baths and disinfestors were organised to carry out these measures. Approximately 51,000 persons, which comprised about a quarter of the force were inoculated with Cox's type vaccine given in three doses of 1 cc. each at weekly intervals. There were only two deaths and the incidence in this group was 0·37 per 1,000. The incidence amongst the approximately 1,55,000 unprotected personnel was 0·91 per 1,000 and total number of deaths was 33. No case of typhus was recorded in a fully immunised individual, i.e., six weeks after the third dose of vaccine.

Castaneda (1942) had advocated the use of bivalent vaccine (mouse-lung epidemic strains and rat-lung murine strains) in three or five doses at weekly intervals. Castaneda and Silva (1944) noted from further experimental work that animal lung vaccines from animals infected intranasally by both epidemic and murine rickettsiae (bivalent vaccines) were more effective against subsequent infection with epidemic strains than vaccines of epidemic origin alone.

The most striking clinical feature was that 55 per cent. of deaths in cases from North Persia were due to circulatory failure or pulmonary oedema whereas no case in South Iraq was noted as having either of these complications. In South Iraq there was a very high

incidence of mental symptoms suggesting a neurotropic type and bronchopneumonia was also more frequent.

On post-mortem examination, massive haemorrhages in the pericardium and into the wall of caecum were seen in two fatal cases which had earlier presented symptoms of acute abdomen. Histological examination of brain in fatal cases revealed typical wolbach nodules associated with small vessels. But some nodules were seen which had no apparent connection with the vascular system. The primary lesion was a proliferation and hyperplastic swelling of the small blood vessels leading to their thrombosis. Perivascular collections of cells, chiefly mononuclear, appeared and developed into tubercle like collections of cells surrounding the necrosed lumen of an occluded vessel. Diffuse infiltration with mononuclear cells and appearance of nodules were also seen between the muscle fibres of myocardium.

Weil-Felix reaction in the troops was 1 in 100 or over in 24 per cent. in the first week, 1 in 1,000 or over in 30 per cent. in the second week and in 50 per cent. in the fourth week. The corresponding figures for Persian civilians were 1 in 100 or over in 50 per cent. in the first week and 1 in 1,000 or over in 9 per cent. in the second week and 8 per cent. in the fourth week. *Proteus* OX2 was agglutinated at a higher titre among the Persian civilians.

Major L. E. Elkerton, IMS devised a special bed-side agglutination test called the precipitin colloid test (Platinum chloride) in which the antigen was a rickettsial suspension mixed with a solution of platinum chloride.

Rickettsial agglutination tests were performed by Van Rooyen at the Cairo laboratory in 81 cases. Seventy-five cases were found to be agglutinated by epidemic rickettsiae and six cases by murine rickettsiae.

It may be noted here that Castaneda and Silva (1940) reported a rapid bed-side method of performing Weil-Felix reaction. A drop of blood in 5 mm. loop was mixed on a slide with a suspension of *Proteus* OX19 in sodium citrate solution to which 0·2 per cent. formalin had been added and the slide rocked to and fro. In a positive case visible clumps gathered round to the edge within a minute. The addition of a little methylene blue solution to the suspension facilitated the observation.

Steuer (1942) carried out dry-blood agglutination test in Poland for quick and extensive surveys with suspensions of *Proteus* OX19. No new principle was involved; tests were made on the same lines in the early days of the widal reaction. Besides actual infection with typhus, inapparent and mild infection, specially in children was detected. The technique employed was evolved by Kudicke and Steuer in which measured drops of blood were allowed to dry on a slide and measured quantities of *Proteus* OX19 suspension added. The dried blood could be used for the test any time up to several days. Bardhan, Tyagi and Boutros (1944) carried out 'dry blood agglutination test' for typhus fever on 640 Egyptian labourers from military camps employing a modification of

Kudicke and Steuer's technique. Drops of concentrated suspensions of *Proteus* OX19 and OX2 were added to two dried films of blood, separated from each other by a stroke of grease-pencil. After a minute, the slide was well mixed with gentle rocking movement and the results read with naked eye or a pocket lens. A positive reaction with *Proteus* OX19 was obtained in 13 cases; of these seven gave positive results with standard Weil-Felix reaction. Three of the seven reactors were found to be suffering from typhus, two were convalescents and the remaining two could not be subsequently traced. Sera of 33 slide negative cases did not react with standard Weil-Felix reaction. The authors conclude that subjects with typhus always gave positive results with dry blood test, but the reaction may become positive in cases other than typhus. In some cases dry blood test was positive when Weil-Felix reaction was negative.

Animal transmission experiments were carried out by Major J. Bowie, IMS with the cooperation of Major C. H. Van Rooyen. Nineteen series of guinea-pigs could be successfully infected from fifty-two cases or convalescents of typhus fever. Most successful results were obtained when suspension of leucocytes was used as the inoculum. Van Rooyen found that the Iraq and Persian strains differed from and were more virulent than the Egyptian strains, producing a tunica reaction in guinea-pigs but not true orchitis. They were also characterised by minute peritoneal haemorrhages and presence of frequent nodules in the animals' brains which were never seen in guinea-pigs inoculated with the Egyptian strains.

PREVENTIVE MEASURES IN THE EIGHTH ARMY

In the Eighth Army in Italy over 85 per cent. of troops were inoculated. Anti-louse powder (AL 63) was used and bathing facilities were provided.

NAPLES

The greatest epidemic of louse-borne classical typhus which confronted the Allied armies was at Naples in December 1943. The cases steadily began to rise in January 1944, and a total number of 1,600 cases were recorded. A huge organisation was set up for the control of the epidemic (Stuart-Harris, 1945; Chalke, 1946). In the early stages protective measures included intensive case-searching and ringing of contacts with barriers of insecticides such as AL 63 and MYL (containing pyrethrum). But the greatest achievement was the introduction of disinfestation with 10 per cent. DDT with the help of mechanical blowers such as dustguns (hand dust sprayers or Dobbins dust sprayers) from 1 January 1944.

This measure which was employed on an extensive scale controlled the epidemic in a very short space of time.

NORTH WEST INDIA

A quite extensive epidemic of nearly 800 cases occurred in North West India among labourers constructing air landing grounds on the

Persian lines of communication (Schlesinger, 1944). Prompt delousing arrangements at recognised stages along the railway and road leading to Quetta prevented a serious spread of the disease into India. Few troops were stationed in these areas but seventeen caught the infection and one died.

APPENDIX A

Scrub Typhus Investigations in South East Asia by the Scrub Typhus Research Laboratory[1].

COMPOSITION OF SCRUB TYPHUS RESEARCH LABORATORY AND ITS AIMS

The SEAC initiated a new unit, the Scrub Typhus Research Laboratory to be based in Imphal, in 1945. The GHQ Field Typhus Research Team, which was functioning at Addu Atoll, came to Imphal and merged with the Scrub Typhus Research Laboratory in March 1945. MRC selected certain civilian and RAF experts who were also attached.

Dr. R. Lewthwaite had been appointed field director of the MRC Scrub Typhus Commission and he was instrumental in raising and supporting the Imphal team, in collaboration with ALFSEA and GHQ. Dr. Kenneth Mellanby was later appointed as Dr. Lewthwaite's deputy for the furtherance of field research, and he visited the team for a period in 1945. The complete staff of the composite laboratory consisted of the following :—

Scrub Typhus Research Laboratory, SEAC.
- Lieut-Colonel J. R. Audy, RAMC—Officer Commanding the laboratory.
- Squadron-Leader C. D. Radford, RAF – Acrologist.
- Major H. M. Thomas, RAMC – Experimental Biologist.
- Flight-Lieut. A. A. Bullock, RAF – Botanist.

GHQ Field Typhus Research Team.
- Major S. L. Kalra, IAMC – Pathologist.
- Major M. L. Roonwal – Mammalogist.

Civilians selected by MRC.
- Dr. H. C. Browning – Experimental biologist.
- Mr. T. M. Gordon—Associate of Dr. Browning.
- Mr. K. L. Cockings—Friends Ambulance Unit.

Twelve NCOs served as technicians or general duty personnel.

The aim of this composite laboratory was to initiate intensive research in order to fill the many lacunae in current epidemiological knowledge.

The early problems facing the investigators from the epidemiological point of view were : (a) confirmation of the identity of the disease in the SEAC, (b) distribution of the disease and its relationship to terrain, (c) the vector or vectors in the Indo-Burma theatre, (d) bionomics of the mites, (e) importance of rodents as reservoirs of infection, and (f) field trials of vaccine (Operation Tyburn). With the very rapid

[1] Parts of the epidemiological section are derived from the various war time reports submitted to GHQ and particularly the War Office Report of March 1947 (3 volumes) on *Scrub Typhus Investigations in South East Asia* and papers contained therein by Lieut.-Colonel J. R. Audy. Some of these investigations are summarised in a paper on the practical aspects of scrub typhus in the field by Audy (1949).

advance of the Fourteenth Army beyond Imphal, and with the increasing pressure of field investigations, it became impossible for the laboratory to supervise the field trials of the vaccine effectively.

MITES AND THE HOSTS

TROMBICULID MITES IN ASSAM AND BURMA

In Manipur and Burma, 12 genera of *trombiculid* mites and a total of 41 species were recorded. Of these 14 species had already been described in literature and the remaining 27 were new species some of which were described by Radford and others by Womersley, with acknowledgement to Lawrence of the Imphal team, and also by certain members of the USA Typhus Commission at Myitkyina, North Burma. Eleven species were common to both Manipur and Burma. The commoner species of mites were *Trombicula deliensis* Walch 1922; *Ascoschongastia lanius* Radford 1946; *Ascoschongastia kohlsi* Philip and Woodward 1946; *Ascoschongastia cockingsi* Radford 1946 (considered to be synonymous with *Ascoschongastia indica* Hirst); and *Schongastiella ligula* Radford 1946. *Walchia glabrum* Walch 1927 and *Walchia enode* Gater, were of less frequent occurrence.

But in Manipur area and Kabaw Valley, *T. deliensis* was by far the most common and widespread species encountered. The most widespread species in South Burma was *Ascoschongastia indica* but the vector mite in both central and South Burma was *T. deliensis,* though its distribution appeared to be less widespread than in territories to the west of Chindwin.

SEASONAL VARIATIONS

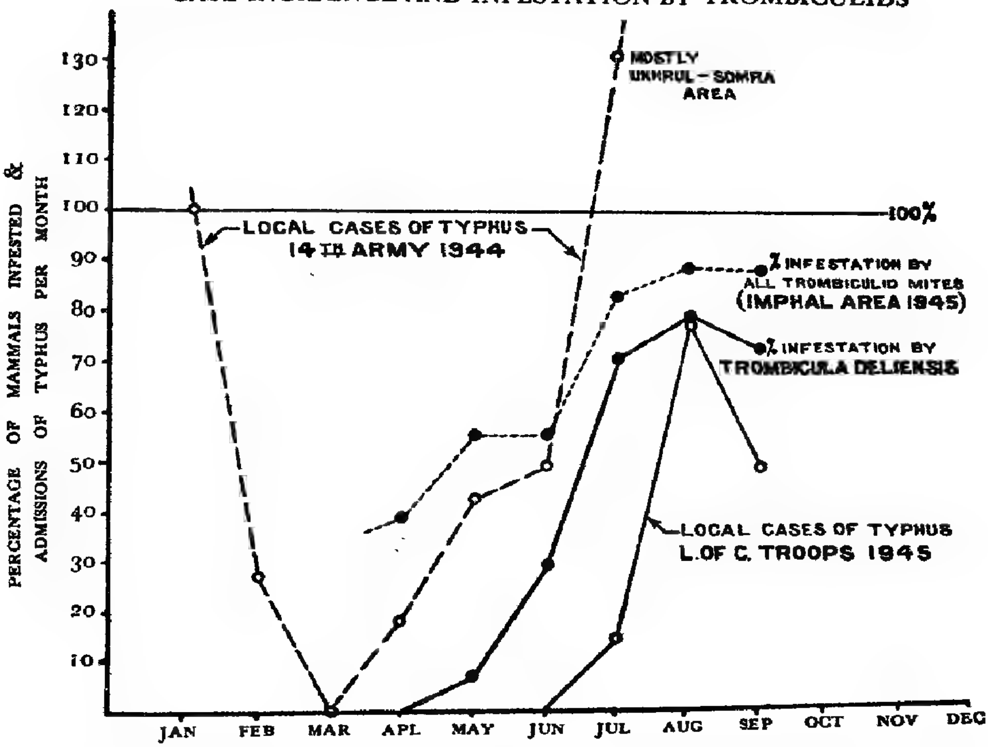
Audy observed that the seasonal incidence of the larvae of *T. deliensis* was very marked in the Imphal-Tamu area in 1945, and was followed by a rise in the incidence of scrub typhus. In Imphal, according to Audy, the larval mite infestation of rats was on the increase in June and the peak was reached in July, August and September.

The seasonal variations were marked particularly with *T. deliensis* which appeared in great numbers in the hot wet season and with *Ascoschongastia lanius* and *Ascoschongastia kohlsi* whose peak immediately followed that of *T. deliensis* in the ensuing cold dry season. Since *Ascoschongastia* species have a wide distribution and a fairly rapid rate of turn-over, Audy has suggested that their potentialities as possible intermurine vectors of scrub and murine typhus should be investigated. Audy has emphasised the epidemiological importance of the locally prevalent intermurine vectors in keeping up the intensity of an enzootic of *tsutsugamushi* infection among small wild mammals. This, in turn would determine the intensity of infection amongst the man-biting species. In addition, Audy suggested that there was evidence to suppose that a wild or jungle-*tsutsugamushi* infection formed the background

of the endemic infection transmitted by *T. deliensis* and *T. akamushi* which had 'escaped' into rat-infested waste lands that appeared following the clearing of forests. In Japan, Formosa, Assam and Burma, the highest incidence of scrub typhus coincides with the summer and monsoons which provide suitable moisture and temperature conditions for the survival and activity of mites. Kalra and Radford observed that similar occurrence of peaks in July and August at Addu Atoll in the absence of seasonal and population factors indicated as though the mite had acquired a developmental rhythm of its own which was not a direct consequence of meteorological conditions.

GRAPH I

SCRUB TYPHUS
SEASONAL CHANGES ON ASSAM-BURMA FRONT
CASE INCIDENCE AND INFESTATION BY TROMBICULIDS



ESTABLISHMENT OF THE VECTOR OF TSUTSUGAMUSHI DISEASE IN ASSAM AND BURMA

The vector in Assam and Burma was definitely considered to be *T. deliensis* supported by the following evidence.

(a) *Recovery of Infection :* Six strains of *R. tsutsugamushi* were recovered from the following batches of mites (Browning and Kalra, 1948). Two strains were recovered from pool of mites which were pure cultures of *T. deliensis* larvae. The four other strains were recovered from pool of mites which contained more than one species but

T. deliensis was present in all batches though sometimes in very small numbers. Other species of mites included *Ascoschongastia* species, *T. deliensis*, *Walchia* species, *Schongastia vieta*, *Neoschongastia* species, *Schongastiella* species and *Trombicula* Sp. Nov.

1. 250 larvae, probably a pure culture of *T. deliensis* but possibly contaminated with a few *Neoschongastia cockingsi*, taken from five *Rattus rattus* sub-species trapped at Mite Hill in August 1945.
2. 60 larvae, *T. deliensis* and *Neo. cockingsi near*, *N. indica* Hirst, from a *Rattus rattus* sub-species trapped at Tamu.
3. 300 larvae, *T. deliensis*, from two rats (*Hadromys humei*), from Palel.
4. 75 larvae, *T. deliensis* and *Sch. ligula* from a *Rattus rattus*, also from Palel.
5. 300 larvae, of species five including *T. deliensis*, from *Rattus rattus*, sub-species, also from Palel.
6. 100 larvae, *T. deliensis* and *Neoschongastia* Sp., from *Rattus rattus*, also from Palel.

(b) In Mandalay, Browning and Kalra recovered rickettsiae from five white mice out of 50 animals exposed as larval baits in pin-pointed areas at the inner edge of a moat near the south gate of Fort Dufferin. The only mites picked up in this site were *T. deliensis*, and although these were not found attached to infected mice, infestation could easily have been missed in circumstances of the field work. It was later shown by Audy that local wild rat was the most successful animal bait to pick up larval mites. White rat came next, as also demonstrated by the American Typhus Commission. White mice proved themselves to be very poor animal baits for picking up larval mites.

(c) Predominant species of mite. *T. deliensis* was found in every one of the pin-pointed typhus islands investigated, usually as the dominant species. *T. deliensis* was also found to infest rats freely *in situ* at milestone 34 Palel Road where Browning himself contracted typhus infection.

Investigations by Radford in Ceylon showed that 98 to 99 per cent. of larval mites infesting mammals at Mount Lavinia were *T. deliensis* with an occasional *Schongastiella* Sp.

BIOLOGICAL FACTORS INVOLVED IN THE LIFE-CYCLE OF TROMBICULA DELIENSIS

The length of time the larva takes to complete its feed varies greatly with different species. Observations at Imphal were mostly gleaned from larval light-trap which was designed to collect live engorged mites from rats. This was based on the observation by Thomas that the larvae were positively phototactic. It was found that *Walchia* species and *Schongastiella ligula* fed for four weeks or more, *Ascoschongastia* species (*A. kohlsi* Philip and Woodward and *A. lanius* Radford) fed for a week (five to ten days), whereas a very short feeding time of two to four days was observed in case of *T. deliensis* and Tr. n. Sp. 'L'. The short feeding time of a few days appears to be shared by all members of the *Trombicula* generic group, for in addition to *T. akamushi*, it also obtains with *T. autumnalis* and *Eutrombicula alfreddugesi.* The number of feeds

in unit time with *Trombicula*, *Ascoschongastia*, *Schongastiella* and *Walchia* species would be in the respective proportions of 8 : 4 : 1 : 1. The monthly turn-over of different species calculated on this basis amounted to 24,000, 12,000, 3,000 and 3,000 larvae per 100 rats per month respectively. The overall turnover of larvae of different species, calculated on this tentative basis as well as on figures based on observations on intensity of infestation in the field, was as follows :—

TABLE I

Overall turnover of larvae of different species.

Species	Turnover in larvae per 100 rat population per month.	Duration of peak infestation month	intensity at peak months mites/rat	Average infestation at peak months. (percentage)
Trombicula deliensis ...	64,000	4	100	80
Ascoschongastia spp. ...	21,600	3	60	60
Schongastiella ligula ...	3,200	3	40	80
Walchia spp.	900	3	30	30

This overall picture did not correspond with reality on a microscale in the field, but it was nevertheless highly significant. This high rate of turnover decidedly gave certain biological advantages to *T. deliensis* over other species of mites and at once placed it in a special position which could be related to its efficiency as a vector. Audy has observed that this high rate of turnover of *T. deliensis* and the great number of separate acts of feeding is related to the following.

(a) The opportunity for dispersal of mites is increased.

(b) The opportunity for evolution of a biologically successful polytypic group of inter-related species *tsutsugamushi* group in different geographical areas. *T. deliensis* and *T. akamushi* represent the extreme forms of the same group (Gater, 1930) and many intermediate forms occur between them. The occurrence of three new species of *trombiculid* mites closely related to *T. deliensis* was recorded at Imphal. These possibly were sub-species of *T. deliensis* itself.

(c) The opportunity for perpetuation and dissemination of *tsutsugamushi* infection transovarially acquired.

(d) The opportunity for encouraging the infection whenever a colony of wild rats remains long enough on an infected *T. deliensis* ' island '.

(e) The opportunity for the rickettsiae itself to be adapted to life in mites of the *tsutsugamushi* group and their principal hosts.

(f) The importance of a restricted group of mites responsible for most of the *tsutsugamushi* enzootic among different animal hosts and similar importance of two closely related species responsible for transmission of infection to man. *T. akamushi*, according to Japanese workers, would attach to man ' with alacrity '. *T. deliensis*, on the

other hand was found by Audy and members of the USA Typhus Commission to be reluctant to attack man. But it did not appear to have marked host preferences and would even attach to an unnatural host such as man.

THE LIFE-CYCLE OF THE VECTOR, TROMBICULA DELIENSIS

The adults lay eggs in the soil which hatch out into larvae in one to two weeks, under favourable conditions. The larvae represent the parasitic phase of the life-cycle and will attack small mammals or human beings if they happen to be in the vicinity. They usually feed only once in their life time. The adults and nymphs on the other hand are non-parasitic. Cockings, during his observation on breeding of *trombiculid* mites in the laboratory noted that isolated nymph did not thrive but nymphs reached maturity in tubes containing many mites. Observations by Jayewickreme and Niles (1946) and Wharton and Carver (1946) have also demonstrated that nymphs and adults of *trombiculid* mites are predaceous and not vegetarian as supposed by Japanese workers.

(a) *Nymphs and Adults :* Thomas observed the changes which took place in the development of the nymph of *T. deliensis*. Replete larvae after detachment from the host wandered freely in the soil but became akinetic any time in the first four days after detachment. Akinesis was preceded by distension of the larva when it became taut and sub-elliptical in shape with rigidly extended legs. The presence of free moisture seemed to be a great aid, if not essential, to the onset of akinesis and this suggested an actual imbibition. Akinetic larvae were usually found to be struck on to the substrate. Incidental observation in the laboratory strongly suggested that contact with a rough surface was an important factor in the process of settling down and a relatively high temperature hastened all the processes involved. Histolysis of the tissues in the legs of the akinetic larva took place very quickly, the products being taken into the body within a thin membrane. This new structure within the larval cuticle, posterior to the legs and mouth parts, and resembling rather like an elongated lemon in shape, was the nymphophane itself. Thomas considered that the dorsal cone of nymphophane was not an organ of escape, as described by the Japanese workers, but was primarily a projection within which sensillae developed. Two ventral discs on the nymphophanal envelope marked the site beneath which the anus of the nymph would develop. The development of the nymphophanal envelope within the larval skin was tantamount to true eodysis, although the skin was not shed. Larvae took eight to fourteen days from akinesis to emergence of the nymph. A large number of nymphs were reared in the laboratory by Cockings. Adults were obtained from some of these but egg-laying was not observed. Sections of outbred nymphs, as Kalra reported, contained a disorganised anatomy and only the gut and ganglion were formed. The contents of the gut appeared amorphous and remained full of granular material all through the nymphophane. During the change from larva to nymph, a more or less complete dissolution of the larval organs, except the ganglion, occurred inside the larval skin. In the

ganglion the fibrous layer increased in proportion to the cellular layer and the whole organ looked larger than before. The emerged nymph acquired an extra pair of legs, mouth parts were re-formed and long hairs appeared to grow all over the body. The salivary glands re-formed and the gut wall became more than one layer thick. The sexual organs developed during the change from nymph to adult. The change from nymph to adult was a considerable one but the naked eye difference was only that of size. Breeding experiments by Cockings suggested that the nymph made the greatest specific demands on the environment, for adults which had achieved maturity in the field laid eggs freely in soil which appeared poor material for breeding nymphs. Investigations in Manipur showed that adults and nymphs were found in situations which embraced great ecological differences. But this was supposed to be due to dissemination of the mites over a wide area and often in unsuitable environments due to habitat and behaviour of the hosts. Audy noted from numerous small observations carried out in Manipur area that though *T. deliensis* was apparently facultative and could thrive in almost any moist soil, yet the most favourable soil appeared to be a fine-textured loam in which the organic matter was being broken down by a rich bacterial flora. Kalra observed that in Imphal area, mites were found in five out of six soil samples which were alkaline (pH 7·1 to 7·7), whereas in acid soils (lowest pH 5·0) mites were present in only 6 samples out of 25. Acid soils with a large quantity of raw humus and a high fungal content did not encourage the mites. The moisture content in which the mites were present varied from 19 to 43·2 per cent. During the dry period preceding the monsoons, adult mites were only found in most shaded places such as seepages and water holes. On the Ukhrul Road, adults were present in practically every gully where the soil was loose, shaded, covered with fallen leaves and kept moist by a small amount of water flowing through it. Culture of selected sample of soils by Kalra for fungi and bacteria revealed that, in general, adult mites were present in soil which were richer in bacteria and poorer in fungi.

Breeding experiments by Cockings suggested that the life-cycle of *T. deliensis* under optimum conditions would be six to nine weeks. This would mean that the mites would complete their life-cycle twice or even thrice during the 'typhus season'. In Imphal and lower Burma investigations on fluctuations and peaks of mite population revealed that the life-cycle of *T. deliensis* in nature was in the neighbourhood of ten to twelve weeks.

(b) *Parasitic Larvae :* The peak infestation occurred during the summer rains when the moisture content and temperature of the soil was high and a rich microflora was present. The high atmospheric humidity and temperature with the onset of monsoons provided ideal conditions for small insect life. The luxuriant vegetation in the form of grassy herbaceous undergrowth in monsoon and evergreen forests, in neglected plantations and in rural waste lands, provided food and shelter to rats and made them abundantly available to the larval mites.

Ecological Observations on Experimental Field Infestation of Rodents : Audy (1947) observed that on a small scale, the restriction of species of mite to 'islands' was notable and this was presumably associated with mite ecological factors, restricted range of the hosts and chance introduction. In a particular area near the research laboratory, *T. deliensis* was common on the hill-sides where *Schongastiella ligula* was not particularly common, but the position was reversed in the nearby village. An interesting example of the small scale distribution of mites in 'islands' was found in a strip of scrub with scattered trees behind two camps at Kanglatongbi. One hundred and nine mammals, mostly *Rattus rattus* were trapped in areas about 50 ×50 yards from one end of the strip to another on successive days for a fortnight. The character of infestation showed two overlapping islands corresponding to two different species of *Ascoschongastia.* As there was no noticeable change in the vegetation types, it seemed probable that a restricted range of hosts was the probable explanation for these two overlapping islands.

Observations on rat infestation in zones proximal to the research laboratory in the camp perimeter and in distal zones revealed that rats placed as larval baits in the proximal zone had a 17 per cent. chance of picking up about four mites, whereas those in the distal zones, only 50 yards or so away in apparently identical scrub, had a 7 per cent. chance of picking up less than two mites. The odds against the observed differences being due to chance were at least 200 to 1. The camp perimeter proximal to the laboratory and disused kitchen were sites of attraction for rats and the experiment provided evidence that there was a significant rise in the free living larvae on the ground as the rat infested camp perimeter was approached.

A field experiment was undertaken at Kanglatongbi in January 1946, with the object of comparing the two most obviously different habitats for *trombiculid* mites namely scrub and forest. About 30 rats at a time were placed at 10 feet intervals from oak scrub covered with tall dry grass, down a slope into a monsoon forest belt through which a stream flowed. The intermediate zone which was dense and characterised by a particular grass, supported the highest population of mites. The difference between scrub and forest was not as marked as could be expected because the investigations were undertaken during the dry season when the pick-up of mites in known endemic foci ebbed to a very low level. Evidence was produced on a number of occasions that an increased rat population in a restricted area, if encouraged and maintained for some time such as in camps and plantations, would lead to a raised mite population and consequently increase the endemicity of scrub typhus.

Larval Hosts : Roonwal (1948) undertook the investigations in connection with systematic, ecological and binomical studies on mammals. The chief host rodent in Imphal area was identified by him as *Rattus rattus bullocki.* The list given below was prepared by Lawrence of important hosts for *T. deliensis* in Manipur and Burma, the identification being made by the British Museum (Natural History), London.

Rodents	*Murids*	*Rattus rattus bullocki*	Roonwal
		Rattus manipulus	Thomas
		Rattus rattus	Linn
		Rattus rattus tistae	Hinton
		Rattus Fulvescens	Gray
		Diomys crumpi	Thomas
		Hadromys humei	Thomas
		Bandicota bengalensis	Gray and Hardwood.
	Squirrels	*Callosciurus pygerythrus*	Variety
		Callosciurus lokroides	Hodgson
		Dremomys lokriah	Hodgson
Insectivores	Tree shrew	*Tupaia belangeri belangeri*	Wagner
	Shrews	*Suncus coeruleus fulvocinereus*	Anderson
		Suncus griffithi	Horsfield
Larger mammals		*Muntiacus muntjak*	Variety (Boddaert) Barking deer
		Macacus assamensis	Assam hill monkey
		Felis domesticus	Domestic cat

The American Typhus Commission at Myitkyina found that *Rattus flavipectus yunnannensis* (Anderson), the yunnan buff-breasted rat and *Tupaia belangeri versurae*, the Assamese tree shrew, were the only mammals naturally infected with *R. tsutsugamushi.* Investigations by Radford in Ceylon during April to August 1944, showed that the hosts were *Rattus rattus kandiyanus* Kalaart, occasionally *Suncus coeruleus giganteus* Geoffroy (musk shrew) and *Bandicota malabarica.* At Addu Atoll the hosts were secondarily, *Suncus coeruleus,* and primarily, a rat identified by Radford as *R. norvegicus* but which may in fact have been a local form of *R. r. alexandrinus.* The favourite site for the larvae to attach were in the cusps inside the external ear of rats where they were found in clusters, in the ears of bandicoots and in the bare skin on the hind thighs of shrews just beneath the hair margin. Larvae were seen in the ears of shrews in Kumaon. The skin tissue of host was dissolved by the action of saliva of larvae which pierced the skin with its mandibles. The saliva itself with the degenerated tissue formed a hard stylostome in the skin where nonspecific inflammation with marked dilatation of skin capillaries occurred, sometimes leading to microscopic areas of necrosis. The exuded lymph and cellular exudate were gradually sucked in by the mite. When the larva detached itself, stylostome was thrown out and left behind in the host. It was not absorbed but remained embedded in the cellular exudate and could be seen in the scab with which it was extruded. The stylostome measured from 67 to 270 μ. The diameter was more constant and was generally 30 to 32 μ and the central duct was 3 to 4 μ wide.

The hosts, all of which are of epidemiological importance, fall into two categories. Some, such as the locally common murids of the genus *Rattus* would act as most efficient potential reservoirs of infection due to their great abundance and a tendency to form compact colonies.

Others such as barking deer and monkeys and also many birds, e.g., crow pheasants (*Centropus* species) would act as itinerant reservoirs and would disperse the *trombiculid* mites over a wide area.

It was found that a proper understanding of the habitat of rats and other small mammals could be applied to a survey of scrub typhus as regards ecology and distribution of the disease. Since the infection in mites is transovarially acquired, the dispersal of mites depending on the behaviour and habitat of the hosts would give rise to numerous scattered foci of infected 'mite islands'. Intensity and duration of the 'mite-rat-mite' cycle would largely determine the occurrence of 'typhus islands'. If it is assumed that larval mites can pick up infection from their hosts, this would mean further spread of the disease by starting new lines of infection. Investigations by Audy in Manipur and Burma showed that the endemicity and extent of 'typhus islands' fluctuated quite apart from seasonal variations. Audy observed that various factors, such as restricted range of adult and larval mites themselves, restricted range of hosts, the population of hosts, the need for a sufficient overlap between mite and host habitats to ensure a mite-rat-mite cycle and the chance introduction of both larval *trombiculid* mites and *R. tsutsugamushi*, were involved in the whole process.

ISOLATION OF STRAINS OF RICKETTSIA FROM VECTORS AND HOSTS

It has already been pointed out that Parker (1944) in collaboration with Savoor, succeeded in isolating rickettsiae identical with *R. tsutsugamushi* from cases occurring in Burma border and Calcutta in December 1943. Kalra succeeded in isolating 19 strains of *R. tsutsugamushi* from different sources. Five of these strains were recovered from the blood of patients suffering from scrub typhus. Three patients had no eschar while in the remaining two, including Dr. H. C. Browning, a member of the Scrub Typhus Research Team, typical eschars were present. It was proved that inoculation of whole blood gave as good results as ground blood clot. The quantity inoculated was 5 cc. in guinea-pigs and 0·5 cc. in mice. Guinea-pig brain was passaged into mice on the fourteenth day irrespective of whether the animal developed any temperature or not.

Six strains of *R. tsutsugamushi*, as already stated, were recovered from pool of larval mites parasitic on rodents trapped in the Tamu-Palel area.

Eight strains of *R. tsutsugamushi* were recovered from the following rodents, *Rattus rattus* sub-species: *Hadromys humei* Thomas; Field mouse (Leggada Sp.?); *Bandicota bengalensis* and *Tupaia belangeri belangeri* (Tree shrew). Strains were recovered from the brain as well as blood of rats, which proved that during the typhus season rickettsaemia was present in rats. 0·5 cc. to 0·75 cc. of blood was obtained from rat by cardiac puncture and inoculated intraperitoneally into a mouse. This was a convenient method and lessened the chances of contamination from extraneous sources. Of 10 rats trapped in an endemic foci, rickettsiae

could be recovered from the blood of three rats but brains of two of these were negative. Though experimental infection of mites in the laboratory could not yet be proved, there was some evidence that mites acquired infection from rodents at least during the 'rikettsaemic phase'. Hence examination of blood of rodents was an effective criterion of the presence of active infection in any area. At Paungde, the pool of brains used for the isolation of rickettsiae, unfortunately consisted of seven bandicoots *B. bengalensis* and one *Rattus rattus*. So it was not possible to indicate whether the strain originated from the rat or the bandicoot. In April, May and June 1945, no strains could be isolated at Imphal. But in September strains from rats from different areas were recovered even when small numbers of them were examined. This indicated high infection rate (25·8 per cent.) in rats during the 'typhus season'.

In the Imphal area, Kalra succeeded in isolating a strain of rickettsia of tick typhus from the ticks *Haemaphysalis leachi* var. *indica*. The host *R. rattus* variety near *R. rattus brunneusculus* Hodgson, trapped in an endemic scrub typhus focus, at mile 34 on Imphal-Tamu Road, was infested with both ticks and larvae of *T. deliensis*. The blood of the rat yielded a strain of *R. tsutsugamushi* but mites did not show any infection. It was considered that the rat and ticks had both acquired separate infections previous to contact with each other. Kalra and Rao (1948) carried out investigations in the Kumaon hills during the period August to October 1948, when the GHQ Field Typhus Research Team functioned there. A total of 21 strains of *R. tsutsugamushi* and seven of tick strains related to *Dermacentroxenus rickettsi* were isolated. Of the R. *tsutsugamushi* strains, eight were from rats and five from seventeen batches of mites, collected in the forest around the three lake areas, Bhim Tal, Nakuchia Tal and Sat Tal. The mites harvested from trapped rats consisted of both *T. deliensis* and *Ascoschongastia indica* Hirst, the former being the predominant species in each pool. Trapping of rats around a bungalow at Bhim Tal, where a case of *tsutsugamushi* disease occurred, yielded one strain from a rat and another strain from mites harvested from four rats. At Naini Tal two strains of *R. tsutsugamushi* were recovered, one from a bandicoot and from a patient and the other from mites. Three strains were isolated at Almora, one from a patient and the other two from mites. At Ranikhet, one strain was recovered from batches of mites identified as *Schongastiella ligula* Radford 1946 but the presence of an odd specimen of *T. deliensis* could not be excluded.

Tick typhus infection was found in *Rhipicephalus sanguineus* ticks at Bhim Tal (five strains) and *Ixodes ricinus* at Almora (two strains).

TSUTSUGAMUSHI INFECTION IN LABORATORY ANIMALS

Kalra observed that several serial passages in white mice were necessary before the strains of *R. tsutsugamushi*, recovered during the field investigations from man, mites and rodents, could be adapted to

their new hosts. Mite strains were most consistent and could be established in mice mostly in the third or fifth generation, human strains could be established in mice in the sixth or seventh generation and a rather variable reaction was obtained with the rodent strains. The microscopical picture of the peritoneal smears during the early stages of adaptation of the rickettsiae to mice was also characteristic. At first extensive vacuolation of endothelial cells and few inclusion bodies were seen. Kalra correlates the vacuolisation in the early stages with the increase of serous exudates which become sticky in the later stages. In the subsequent passages, increasing number of inclusion bodies and a few typical rickettsiae appeared. Later, the inclusion bodies diminished and fairly large clusters of rickettsiae were seen in the cytoplasm, sometimes encroaching on the nucleus. Kalra concludes that inclusion bodies are a phase in the developmental cycle of *R. tsutsugamushi* during the stage of adaptation to a new host. He also suggests that antigenic structure of the particular rickettsiae may be modified in a new host resulting in typical reactions and alterations of the Weil-Felix response. The typical post-mortem appearances in infected white mice were a thin serous exudate in pleural cavity, sticky peritoneal exudate, enlarged spleen and pale liver. The presence of pleurisy and variable quantity of peritoneal exudate was pathognomonic of the infection even in the absence of rickettsiae. *R. tsutsugamushi* were stained violet with Giemsa and were present in clusters in cytoplasm of cells, while large isolated ones showed bipolarity like *B. pestis*.

In the guinea-pigs temperature was not a reliable index of infection. In one guinea-pig terminal rise of temperature was seen as observed in some fatal human cases. A strain isolated from a tree shrew trapped at Palel, produced free exudate in the peritoneal and pleural cavity of guinea-pig with abundant typical rickettsiae in peritoneal smears. Rickettsiae could not always be demonstrated in the peritoneal smears of infected guinea-pig.

Rhesus monkeys developed a local reaction, lymphopenia, rickettsaemia and a rise in OXK agglutinins, when first inoculated with *tsutsugamushi* strains. Temperature response was variable but in a particular animal it was always of the same type with different strains. On re-inoculation the reaction did not occur, suggesting that local immunity was more solid than the generalised immunity, *Proteus* agglutinins did not rise, rickettsaemia and pyrexia did not occur in every animal, while the lymphopenia was related to fever in its magnitude. The results showed that *rhesus* monkey might acquire complete, partial or no immunity whatsoever by one strain against infection by other strains and that it was not a suitable laboratory animal for these experiments. Rickettsiae were observed in the large mononuclear cells. The azurophilic granules in the lymphocytes considerably increased on the third or fourth day and remained so for a fortnight. Similar azurophilic granules were seen in blood films from a convalescent patient.

Kalra found that in the *Rattus rattus* sub-species, the most common rat in Imphal, rickettsiae could be recovered from the blood up to seventy-four days after infection and from the brain up to ninety-nine days. It was suggested that rats served only as a temporary seasonal reservoir since the infection disappeared from blood after seventy-four days and no rat was found infected before the typhus season. The mite itself, therefore, remained vector of the disease as well as the most important permanent reservoir. Rickettsiae could not be seen in spleen smears of 150 local birds examined and there was no evidence to show that chickens, quail or pigeons served as reservoirs of infection.

An attempt was made to infect larval mites experimentally. Wild rats (*Rattus rattus* sub-species) infected in the laboratory were left on the ground in wire cages for twenty-four hours as bait for larval mites. In the laboratory they were left undisturbed for another twenty-four hours to give the mites a chance to partially engorge themselves before removal. Rickettsiae could be recovered from two batches of pooled mites out of a total of five. Nine batches of mites trapped from the same area served as control and all of them were negative. Although the experiments were not conclusive since laboratory bred mites were not used, there was a strong evidence to suggest that larvae can acquire infection from rats during the rickettsaemic phase.

Six strains of *R. tsutsugamushi* from patients, mites and rats were proved to be identical by cross-immunity tests on rabbits, and protection tests on mice and monkeys. But notable antigenic differences and variations in virulence were observed between *R. tsutsugamushi* strains from different areas as a result of the same tests namely protection experiments in mice (Blake, Maxcy, Sadusk, Kohls and Bell, 1945) by immunising with one strain and challenging with a different strain and cross immunity experiments as shown in the anterior chamber of the rabbit's eye which did not develop the usual specific intraocular infection on re-inoculation, if immunity was already acquired by a previous infection with a different strain. Kalra observed that this confirmed the view expressed previously (Lewthwaite and Savoor, 1936) that antigenic differences of *tsutsugamushi* strains from different localities could account for the notable variations in the clinical picture of scrub typhus, e.g., changes in severity of the infection as observed from place to place. But the symptoms in any one district were usually consistent. In later studies by Kalra (1948) in the Kumaon hills, it was found that strains locally isolated from patient, mite or rat were immunologically identical. But cross-immunity experiments in rabbits revealed antigenic differences between Kumaon strains and strains from Ceylon and Imphal.

POSITION OF THE VECTORS OF SCRUB TYPHUS

The position of vectors of scrub typhus is summarised below.

Species	Distribution	Considered a vector in
T. akamushi	Japan, Formosa, Pescadores, Malaya, New Guinea, South West Pacific Islands	Japan : ABCD (transovarial and infection in adults also demonstrated). Formosa and Pescadores: A. Malaya : AC. South West Pacific Islands and New Guinea : ABD
T. deliensis	Malaya, Sumatra, Indonesia, Ceylon, India & Pakistan, Burma, Maldives, North East Australia, New Guinea.	Malaya : A (? with *akamushi*) Sumatra : ABC India : AB Burma : ABD (Transovarial transmission established by USA Typhus Commission at Myitkyina) Imphal, Assam : ABD. Queensland : A New Guinea : AB
Neo. schuffneri	Sumatra	Sumatra : C (Exceptional case recorded by Walch).
Sch. blestowei	New Guinea	Parts of New Guinea : A. Scrub itch mite suspected by Gunther unconfirmed.

Legend

A. Epidemiological evidence only (seasonal incidence, coincidence of infections and infestations of man, and usually heavy infestation of local rodents, in ' typhus islands ').

B. Strains of *R. tsutsugamushi* recovered from crushed mites.

C. Found attached to man, later eschar on the same site and an attack of scrub typhus.

D. Has given infection by attachment to laboratory animals.

CORRELATION BETWEEN THE GEOGRAPHICAL DISTRIBUTION OF MITES AND SCRUB TYPHUS

The very wide distribution of scrub typhus in territories as far flung as Addu Atoll, Ceylon and India on the west, New Guinea and Queensland on the south east and Japan and Formosa on the north could be correlated with the similar wide distribution of *T. deliensis*. In Ceylon larvae of *T. deliensis* were identified and incriminated as vector on epidemiological grounds by Audy and Radford. In later investigations in the Kumaon range in the Himalayan foot-hills, Kalra (1948) noted the abundance of *T. deliensis* as the predominant species and could actually recover *R. tsutsugamushi* from batches of pooled mites.

OBSERVATIONS ON ECOLOGICAL FEATURES AND TOPOGRAPHY OF SCRUB TYPHUS IN AREAS INVESTIGATED

The earliest investigations suggested that scrub typhus appeared to be a ' man-made disease ' and later investigations supported this view.

Primitive shifting cultivation has been responsible to a great extent for the endemicity of the disease, first by encouraging an abundance of rat population and secondly by removing the thick canopy of jungle, and thus bringing the rodents down to the grounds a condition apparently very suitable for the life-cycle of many *trombiculid* mites. Air photography has proved useful in the ecological survey of scrub typhus.

Manipur State and Assam : Manipur base (Dimapore) was made by extensive deforestation. The endemicity of the disease was low but it gradually rose as the number of troops at risk were steadily diminishing. The possible explanation for the rise was an increase of the rat population in the camp areas which were alternately abandoned and reoccupied. Several infected foci were seen in the Naga and Chin hills and in the Imphal plain. The type of vegetation was evergreen forest at the higher altitudes and protected gullies and deciduous (monsoon) forest at lower altitudes and open areas. But in many areas forests were replaced by secondary jungle or scrub as a result of shifting cultivation, felling of trees for fuel and scrub fires. Infections at milestones 78-88 on Manipur Road, in Maram area, were from hill side slopes, grassy scrub and small terraced fallow paddy field used as a rifle range. *T. deliensis* was found infesting rats and shrews near mile 81 of this area. In the Kanglatongbi area, at milestones 113-119 on the Manipur Road, an infected focus was found in a grassy areas adjoining a forest belt which followed a small ravine. Rats trapped in this camp were infested with *T. deliensis.* Infestation rate in rats at Kanglatongbi was high in those trapped just outside the villages. Of the rats trapped in Imphal laboratory 60 per cent. were infested.

In the Imphal plain typhus was endemic in the two ranges of low hills which flank the Manipur Road for a stretch of 10 miles north of the township of Imphal. Most of the cases of scrub typhus in the Imphal district originated from the foot-hill camp sites. In the Ukhrul area about a dozen infected foci were encountered, mostly in scrub areas near villages. On the Palel Road, a very circumscribed focus was seen in a water meadow (grassy river bank) $3\frac{1}{2}$ miles east of Wangjing. The site was covered with a dense growth of grass mostly *Imperata* and *Saccharum.* Cases of typhus occurred in camps in the low range of hills on the east side of Palel Road from milestones 22 to 29. A camp by an abandoned air strip near a hillock formed an endemic focus. Rats placed as larval baits in small cages on this hillock picked up larvae of *T. deliensis* fairly freely while rats trapped in the camp were also heavily infested. Palel and Moreh were two important centres of typhus outbreak but the incidence in the central parts of the mountains separating them was low. A pin-pointed focus was found at milestone 34 in the mountain section, where a particular camp site was alternately abandoned and re-occupied. The Tiddim Road area was found to be heavily infected from Bishenpur to beyond Tiddim. The 5th Indian Division suffered about 900 casualties from scrub typhus while advancing along this road, roughly along the course of the Manipur River to the Chindwin. An important ecological feature of an outbreak in Falam district, south of Tiddim, was that the incidence was in a camping area near a water-course. An interesting feature of the infected

camps between milestones 81 and 84 was that very few cases occurred when the area was first 'civilised' and occupied for a year. The area was abandoned due to Japanese advance but when it was re-occupied in August 1944, a very sharp outbreak of scrub typhus occurred. If such camp sites are abandoned and then reoccupied during the 'typhus season', the risk of scrub typhus increases considerably.

BURMA

(i) *Ecological Features :* Patchwork or mosaic of vegetation were studied from air photos in six random square miles (milestones 30 to 50) on the Taungoo—Mawchi—Pasawng Road. There was a complex juxta-position of different ecological units, such as (a) forest, (b) *ponzos* (as a result of *taungya* or shifting cultivation), secondary low forests (bush scrub) and coppices, (c) two to five year old *ponzos*, bamboo *ponzos* and cane brakes, (d) recent clearings and (e) valleys and stream beds with jungle fringes. Sharply focal and pin-pointed distribution of infected areas were characterised by overlapping of fairly precise ecological factors. Relative immunity of the indigenous population was noted. *T. deliensis* was found infesting two out of four squirrels at milestone 16 camp on the road.

Four bandicoots and three rats trapped at Pegu, Thinatpin and environs were infested with *Ascoschongastia indica* and one with *Walchia enode.* Fourteen rats (*R. rattus* sub-species and *R. norvegicus*) in the Pagoda road were infested freely with *Schongastiella ligula* and less freely with *Ascoschongastia indica.* In a suspected area of the suburb of Insein, a *Rattus rattus* sub-species was found heavily infested with *T. deliensis.* Two others from a different site were infested with *Ascoschongastia indica.* Surplus boiled rice thrown away attracted a high rat population around human habitations. In lower Burma, troops frequently contracted infection in waste lands within and adjoining towns and villages. The commonest rodent at Paungde was a bandicoot. Thirty-two animals were trapped and all but six were infested with *T. deliensis*, some very heavily, with the result that their ears were thickly encrusted. Rickettsiae were later recovered from the pooled brains of rodents from Paungde. Among other rodents infested with *T. deliensis* were three *Rattus concolor* and two *Rattus rattus.* The various other species of mites observed in the area were *Ascoschongastia indica, Schongastiella ligula, Walchia* sp., *Walchia enodis*, and *Trombicula* sp.

At Prome, which proved to be a highly endemic focus, troops were found to forage as well as defecate in the surrounding scrub.

The Mandalay area was specially investigated by Browning and Kalra. The dominant species of larval mites on trapped rats was *T. deliensis.* The degree of infestation in the last half of July declined in advance of the decline of typhus. Browning and Kalra compared the rainfall and typhus incidence between equatorial climates (Malaya and Addu Atoll) and monsoon climates (Assam and Burma). It was concluded that rain affected typhus incidence by stimulation of part or all of the breeding cycle in monsoon climates and by inhibition of

activity by free water in equatorial climates. Rats were trapped in the Mandalay area for a period of three weeks and examined for infestation. A total of 57 rats were trapped of which 47 were infested with *trombiculid* larvae. The infestation rate in rats was 92 per cent. in the first week, 100 per cent. in the second week and 66 per cent. in those trapped in the third week. White mice were exposed as larval baits at Fort Dufferin and Sagaing. Three mice from Fort Dufferin area acquired *trombiculids* among 50 animals exposed. All three had been sited on a moat edge in rush-grass association. None of the 50 animals exposed at a particular endemic focus at Sagaing were found infested. The vegetation type in the infected inner moat edge near the south gate of Fort Dufferin (Mandalay) consisted mainly of grass and some area of creeper with rushes and lotus plants at the water-edge. A number of small trees were scattered throughout the area. The vegetation of the compound at Sagaing which was cleared by the personnel of an Indian staging section among whom a few cases of scrub typhus occurred, consisted of sparse grass with a dominant herbaceous weed two to three feet tall. A soil mite survey was carried out by extracting mites in a specially devised ' box ' in which directional influence of light and heat were employed. *Trombiculid* larvae were found to avoid intense light though they were attracted by moderate light. One or more soil samples from 11 different sites were compared experimentally in regard to mite population and its composition. *Oribatids* were dominant, being found everywhere. *Tyroglyphids* ranked next, followed by *Uropods* and *Gamasids*. Some soils, while having qualitative representation of all groups, had one or a few species as overwhelming dominants. Only a single *T. deliensis* (larva) was found despite intensive investigation of individual sites where experimental animal had acquired infestation or infection. The commonest rodent was the bandicoot but later on more rats were seen. The mites infesting the rodents were *T. deliensis*, *Ascoschongastia indica* and *Neoschongastia*. sp. nov.

Experiments and observations suggested that the intermediate zone where jungle met the scrub or some other form of ecological transition occurred, was of great importance in the epidemiology of scrub typhus. The disease was found endemic in the fringe habitats. The hosts in Maymyo Road were squirrels and tree-shrews.

Observation on water-edge at Meiktila and Myingyan showed that steeper banks with vegetation, drains and canals were more important than flat edges of lakes and tanks as they were water logged. Laboratory experiments on breeding of mites showed that both adults and larvae of *T. deliensis* were entrapped by free water films and hence infections were minimal from sopping wet ground. Pockets of hill-wash and hedgerow communities were other ecological features of interest. The hedgerows were a special case of the ecology of marginal zones. They gave shelter to small mammals which shed the replete larvae. An ill kept road-side drain backed by hedgerows under the shade of a tree presented the features of typhus ecology.

In the Indainggale—Kalewa area, many cases occurred among pioneer corps labourers who were employed in clearing road and fetching

metal and stones from nearby. There was an outbreak at Kaing on an alluvial area in the south bend of Chindwin opposite Kalewa. The camp was sited on a grassy area adjoining the village of Kaing and a low lying swampy area through which flowed a stream. From an outbreak in an East African battalion, it appeared that the village of Natkyegon at the mouth of Bon *Chaung*, was a hyperendemic focus. The Moreh area which is a teak-bearing belt of low foot-hills, also appeared to be a hyperendemic focus. From milestones 65 to 68 the hilltops, 1,000 feet to 2,000 feet high, were covered with parkland *ponzo*, grass with scattered stunted palms, oaks and other trees. The valleys were covered with mixed deciduous forest including some poor teak. Seepages were common on the slopes. In August 1944, adults and nymphs of *T. deliensis* were found on a slope adjoining Mite Hill which had been burnt over during the early part of the year. *T. deliensis* were also found on Rhino Hill, one mile further on and along a swathe through the jungle following telegraph wires. During a reconnaissance survey in August 1945, *T. deliensis* was found heavily infesting rats at Mite Hill and Moreh.

Ascoschongastia indica was the common mite from Moreh to Kalewa but it was uncommon on the Imphal plain. It has been suggested that this mite infiltrated from Burma where it is very common and that the Indo-Burma mountain ranges formed an ecological barrier to its penetration further west. An almost pure culture of *T. deliensis* from rats trapped at Mite Hill gave rise to infection after inoculation into a mouse. Bandicoots were common in this area and they were probably the most important 'reservoir' in Burma.

The Kabaw and Kale valleys are alluvial and the forest vegetation is largely *Indaing* interspersed with a mixed bamboo forest. The *Indaings* are dominated by teak like trees (*Dipterocarpus tuberculata*) with large leaves, canopy is open and there is a growth of knee to waist high grass mixed with few other plants and seedlings. There are many grassy banks and the jungle is particularly interrupted by large sweeping areas of elephant grass (*Kaing*) which correspond with S-bends of the streams. There were many scattered foci in these valleys. Wherever pin-pointing was possible, they were always found to be related to habitation or water course. Sayers and Hill (1948) noted a characteristic pin-pointed outbreak in the neighbourhood of Wetyu *Chaung*, north of Tamu. Officers and their batmen who camped on a pleasant streamside spot about 200 yards away from the main body of troops, developed scrub typhus whereas no cases occurred in the rest of the unit.

The incidence of scrub typhus could specially be correlated with two factors. One was association of the disease with tall grasses, 6 to 20 feet high. Miyajima and Okumura (1917) stated that the mites of scrub typhus were associated with the reed *Imperata arundinacea* and daisy *Artemisia vulgaris*. The particular grass in scrub-lands associated with the disease is called *Ulu* in Bengal, *Illuk* in Ceylon, *Lalang* in Malaya and *Kunai* in New Guinea, Australia and South West Pacific islands. The second association between scrub typhus and features of the terrain is with streams, rivers and coastal areas of swampy land.

(ii) *Topography of Scrub Typhus :* The following observations were made on the ecological features concerned.

(a) *Suitable Mite Habitat :* The most suitable soil was fertile loams in which the organic matter was being broken down by a rich microflora. A temperature above 70°F. and a fair amount of moisture was also necessary. Rank growth of grass and leaf-debris cover provided the microclimate and other ecological features necessary for mite life.

(b) Suitable host habitat.

(c) Overlapping of mite and host habitats.

(d) Introduction of infection which is usually fortuitous.

(i) Introduction of a mite congenitally infected.

(ii) Donation of freshly infected larvae by a rat infected elsewhere. These gave rise to an infected second generation.

(e) Perpetuation and boosting of infection by some infected mites in the presence of heavy infestation of a big population of hosts.

Terrain : The following types of terrain were found to be sources of scrub typhus infection.

(a) *Ponzos :* These are clearings reverting to jungle after *taungya* (shifting) cultivation. Fringes of *ponzos* were found to be specially dangerous. Besides these, endemic foci were present in the edges of paddy growing areas and in mountains and foot-hills of Burma, e.g., Mawchi Road, Maymyo Road, Thazi-Kalaw hills, Mite Hill, Rhino Hill and Thaungdup Road.

(b) Neglected compounds and urban and rural waste lands, e.g., neglected sites in Calcutta, Insein, Rangoon, Mandalay and Sagaing and rural waste lands as at Paungde, on the Rangoon—Prome Road, Moreh and other villages in Kabaw and Kale valleys are examples of rural waste lands.

(c) Neglected and ill-kept plantations, e.g., rubber estate in Sumatra, oil palm estates of Kuala Lumpur, sugarcane cutters in Queensland, coconut and banana plantations in South West Pacific islands. These are sources of attraction for rats.

(d) *True Riparian :* Grassy areas, usually covered with species of *Saccharum*, *Sorghum* and other elephant grasses (*Kaing*) which owe their origin to shifting water courses. Some cases in Kabaw Valley appeared to have their origin in restricted *Kaing* banks by streams. There were some true riparian grassy patches between the Prome township and Irrawaddy which was probably infected.

(e) *Forest :* The only instance of infection suspected to have been acquired in virgin forest was possibly between Mawlu and Pinwe near Katha and according to accounts given by members of the USA Typhus Commission at Myitkyina, in some places in Hukawng Valley (e.g., Shinbwiyang). It has been suggested that some non-virginal features were usually seen (e.g., riparian, proximity to *ponzos*, former flowering of bamboos, etc.). The only forests that could be definitely incriminated were coppiced narrow strips which followed streams and were surrounded by scrub. Such a forest belt was at best an example of contaminated virginity.

Within each of the above broad types of terrain, special ecological features as noted below provided the endemic foci.

(a) *Topographical :* These were road-side hedgerows, bank undergrowth, usually grassy, 'fringe' habitats, e.g., edges of *ponzos*, and hill-wash pockets in dry zone. The concept of 'fringe habitat' is that wherever two ecological areas meet, there is an intermediate zone 'fringe', e.g., advancing edge of a jungle, bank of a stream, road-side hedgerow. The 'fringe' has ecological features, characteristic of its own and may harbour a rich flora and fauna, usually in numbers at the expense of species.

(b) *Water :* Water courses, canals, drains, tanks, hill springs, etc., provide foci within all types of terrain. Depth of water level and porosity of soil determine the influence which the local rainfall is going to have, the rate of drying and the risk of water logging.

(c) *Population of Hosts :* This is usually associated with the available food supply, e.g. around the periphery of camps and *bashas*, in villages, stores, rice mills, cook-houses, food and rubbish dumps. Crops such as sweet potato, millet, maize, rice, bananas, etc. cultivated in villages also attract hosts. Plantations such as coconuts, oil palms, fruit crops and less often rubber are other sources of attraction. In nature, seeds of *Dipterocarpa*, flowering of gregarious bamboos, seeds of grasses and vines, fruits of *Solanum* and *Cucurbitus*, offer attractive food to rodents.

Besides, clearing of jungle for cultivation reduces predators, removes restraint of natural food-cycle balance in virgin country and thus tends to increase the rodent population. An effective cover is provided by ricks, habitation dense undergrowth, rubbish dumps and burrows, etc.

RESULTS OF OTHER MISCELLANEOUS INVESTIGATIONS AND VARIOUS TECHNIQUES EVOLVED

(a) Mellanby compared the efficacy of benzyl benzoate as mite repellent with DBP. He reported that it was as good as DBP or perhaps better as a mite repellant.

(b) Bullock carried out an extensive study of the flora of Imphal. His detailed studies included the different vegetation types in the area ; the climax communities and succession ; and the causes which led to these changes. The results of his studies indicated that mites had no preference for any particular vegetation type. Any forest that had a low canopy of shrubs and grasses or other undergrowth provided food and shelter for rats and suitable soil for mite habitation. Such conditions were present in deciduous, subdeciduous and ever-green forests of foot-hills with a tropical or subtropical climate as well as in oak, silver fir and spruce forests at altitudes of 7,000 feet to 9,000 feet in temperate climates.

(c) A special box was designed by Browning to recover mites from soil as the water floatation method was found very unsatisfactory. It consisted of a wooden box, two feet square with nine inches sides. Its bottom was of wire gauze, 40 mesh per inch. The top was a removable

lid with four equally spaced electric bulbs, two 100 watt and two 60 watt. The standard soil sample used consisted of the top $1\frac{1}{2}$ inches of soil and vegetation from four square feet of the selected site. This sample was thoroughly mixed and one-half used. The sample was sieved through 1/4 inch mesh into the box where it formed a $1\frac{1}{2}$ inches layer. The 'drop through' soil from the box was discarded. The lamps were then lit, while a sheet of paper was secured under the mesh to collect soil and mites that dropped through. The box was supported at four corners so that it was raised four inches, thus the paper remained at room temperature. The heat and perhaps the intense light drove the mites to drop on the paper which was removed after two hours and the mites collected.

(d) Browning studied the field anaesthesia used for laboratory mice and wild rats. Bromethol was found to be the best and was used as a routine procedure. 1 to 1·5 cc. of a 1 in 40 dilution injected intraperitoneally gave best results.

(e) A field technique for cutting paraffin serial section of mites was evolved by Kalra and used to study the internal anatomy of mites. A tube was improvised for paraffin infiltration under reduced pressure.

(f) A phototactic light trap was devised by Cockings (1948) which allowed replete larvae to detach naturally from their hosts and be collected for breeding or experiments.

(g) A breeding chamber for experimental studies on mites was evolved.

(h) A practical method of precise survey for typhus risks was devised :

(i) *Assessment of Risk :* Rats were trapped and an infestation rate of one or more in ten with *T. deliensis* signified typhus risk.

(ii) *Endemicity and Distribution :* Trapped rats were anaesthetised and their ears cut out and divided longitudinally. The mites were scraped off with a curette or a blunt scalpel under an electric auriscope. Scrapings were put in saline in a cavity block covered with glass and left over night. The mites which freed themselves from debris were picked off under a dissecting microscope. Batches of mites were washed in saline with a capillary pipette, grounded with a plastic grinder, suspended in 0·5 cc. saline and centrifuged lightly for a minute. The supernatant fluid was inoculated intraperitoneally into guinea-pigs or white mice. The remaining batches of mites were mounted in polyvinyl alcohol for later identification.

Actual endemicity of ground was assessed by placing rats with clean ears as larval baits in $\frac{1}{4}$ inch mesh wirecages, $3 \times 4 \times 7$ inches, systematically on the ground in a pattern for 24 hours. In this way actual infestation of the ground in precise locations could be assessed by the number and species of mites picked up. The information was supplemented by the number of mites from the area found to be infected by inoculation.

(i) A live-rat trap was improvised for rough handling in the field.

(j) Browning devised a trouble-free method of handling trapped animals under anaesthesia.

(k) Kalra and Linder evolved improved histological methods in microtomy and staining of mites.

SCRUB TYPHUS INVESTIGATIONS IN ADDU ATOLL

No. 1 Indian Field Typhus Research Team raised at Poona in September 1944, under the command of Major S. L. Kalra, started functioning at Addu Atoll in the Maldive Islands in November 1944. Squadron Leader C. D. Radford, an expert on mites, also joined the team in December. He had already confirmed the presence of the vector mite, *T. deliensis*, in Embilipitiya and other parts of Ceylon.

Weil-Felix reaction in 385 Maldivians was studied by the research team and it was found that a high percentage showed a positive reaction in dilutions of 1 in 80 or over. Fifty-one pregnant women who were studied did not show any rise of Weil-Felix titre. Gratch (1943) had shown that sera of pregnant women and patients with malignant disease gave a positive Weil-Felix reaction with *Proteus* OX19 in high titre. Nelson and Cruickshank (1945) and Savoor (1944-45) were also unable to confirm the findings of Gratch (1943).

Adults of *T. deliensis* (Walch, 1923) were found in moist shaded soil of compounds away, from the effects of salt spray. *Ascoschongastia indica* Hirst 1945 and *Schongastia maldiviensis* Radford 1945 and *T. acuscutellaris* (Walch, 1923) were the other species of mites identified. Adults of *Neotrombidium* and *Womersleya minuta* Radford 1945 were also seen. The hosts were *Rattus norvegicus* and the shrew, *Suncus coeruleus giganteus* for *T. deliensis*. Buzzard eagle, lizard, grasshoppers served as hosts for the other species. Though no strains of rickettsiae could be isolated at Addu Atoll, circumstantial evidence of the occurrence of scrub typhus was conclusive as no other vector of typhus except mites was present on the island. Though the climate of Addu Atoll was unvarying throughout the year, yet the incidence of scrub typhus for some inexplicable reasons appeared seasonal.

SCRUB TYPHUS INVESTIGATIONS IN INDIA AFTER THE END OF WORLD WAR II

The composite Imphal team, based on Scrub Typhus Research Laboratory, finished its work and broke up in March 1946. In August 1946, Army Headquarters Field Typhus Research Team (Kalra and Rao) continued to work in India, and besides Kumaon hills, investigated other areas such as Jubbulpore, Bangalore, Mysore and Kashmir.

Jubbulpore : Strains of murine typhus were recovered from patients and pooled specimens of *X. cheopis* and *X. braziliensis*. One strain of murine typhus was recovered from ticks, *Boophylus australis*. One case of typhus, clinically and serologically, resembled Rocky Mountain spotted fever.

In Chindwara forest, *R. tsutsugamushi* were recovered from a pool of mites containing *T. deliensis* and also from field mice.

Bangalore : Strains of murine typhus rickettsia were isolated from the rat fleas *X. Cheopis*, *X. braziliensis* and also from rats and bandicoots

trapped in the town. Ticks collected from animals trapped in the town and its suburbs were, however, free from rickettsial infection.

Mysore : Murine typhus rickettsia were recovered from separate pools of *X. Cheopis* and *X. braziliensis* and from rats trapped in the town. No ticks were found infected.

Kashmir : The presence of epidemic, murine and scrub typhus was established. *T. deliensis* was present in every pool of mites from which rickettsiae were recovered.

USA TYPHUS COMMISSION AT MYITKYINA

Mackie (1946) concluded that *tsutsugamushi* disease was widely distributed in Ledo area of Assam and upper Burma. *T. deliensis* was found to be the important vector which could be incriminated. It was shown to attach to man under field conditions and to transmit *R. tsutsugamushi* to susceptible experimental animals during feeding. Experimental proof was obtained of transovarial transmission of *R. tsutsugamushi* in *T. deliensis.* It was observed that the density of *T. deliensis* population in any area provided an approximate index of the risk of infection.

INVESTIGATIONS IN PACIFIC THEATRE

In the Pacific theatre, specially in New Guinea, investigations were proceeding apace. Blake *et al.* (1945) made a thorough study of the *tsutsugamushi* disease in New Guinea. They found that *T. akamushi* was the only mite which could be proved as vector by experiments. There was also much evidence to incriminate *T. deliensis.* Voles (*Microtus montebelloi*) were found infected in nature. Strains of rickettsiae identical with those recovered from men were isolated from *T. fletcheri,* a variety of mite similar to *T. akamushi.* Syrian hamster was found to be a very suitable animal for passage experiments. Kohls, Armbrust, Irons and Philip (1945) also recovered strains of *R. tsutsugamushi* from pools of *T. fletcheri* (*T. akamushi*) and *T. Walchi* (*T. deliensis*) found on the rodent, *Rattus concolor browni.* Rickettsiae were also recovered from this rat. The incriminated terrain in New Guinea and adjoining islands consisted of open *Kunai* grass, abandoned banana and coconut gardens with undergrowth of grass and shrub, sparse coarse growth of native vegetation and areas on the edges of virgin forest. The mites of the 'scrub typhus' areas belonged to a different species from those in the nearby 'scrub itch areas (de Vidas, 1945). The consensus of opinion was that *T. fletcheri* and *T. walchi* transmit scrub typhus while *T. mediocris, Schongastia pusilla* and *Sch. blestowei* cause scrub itch. Philips and Kohls (1945) found larval mites, *T. deliensis,* infesting *Rattus concolor browni* in an uninhabited island. Scrub itch mites were found in boots only and not on animal hosts. Strains of *R. tsutsugamushi* isolated from pools of triturated *T. deliensis* were injected intraperitoneally into white mice. McCulloch (1944) observed that six-legged larval mites were attracted by sweat and remained attached till they were fully engorged. They were most active on warm days

(67°-75° C.), after rains and most numerous on grassy hills. In the list of mite vectors given by Williams (1944), *T. minor* (*T. hirsti*) was suspected besides the usually known ones. A host of animal reservoirs such as rats, field mouse, bush rat, mole rat, bandicoot and musk shrew were described. It was observed in a bulletin of the United States Army Medical Department (1944) that the greatest risk of scrub typhus was at the border between *Kunai* grass and jungle. Larval mites fed on rats, bandicoots, lizards and birds, and man was only an accidental host. Since there was little correlation with scrub itch, 'itch mite' was presumably not the vector. Irons (1946) provided experimental evidence that variations in virulence of *R. tsutsugamushi* to mice were reflected in the severity and mortality rates of scrub typhus in two different areas of the South West Pacific.

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CHAPTER XXVI

Venereology

ADMINISTRATION AND ORGANISATION

Venereal disease problems of the armed forces are mainly concerned with prevention and prophylaxis, diagnosis and treatment in the hospitals, and surveillance and post hospital treatment till the patient is completely cured. The venereologist's duty is not only to keep the men free from venereal diseases and to treat them when diseased but also to return them to the field in a fighting fit condition as soon as possible.

The authorised establishment in the India Command for venereologist and dermatologist combined was only seven prior to World War II. These specialists were assigned to commands and much of their time was spent in touring. The diagnosis of venereal diseases was, therefore, generally carried out by general duty medical officers. Urethral smears were examined in clinical side rooms attached to the hospital wards. 'Dark ground' method of diagnosis of syphilis was undertaken if the hospital happened to be near a well equipped laboratory. Serological tests (Wassermann and Kahn) were performed by trained pathologists in well equipped laboratories. The interpretation of the Wassermann reaction and Kahn test reports in the light of clinical manifestation of the disease was, however, left to the general duty medical officers. Treatment of syphilis cases was usually limited to preparations of arsenic and bismuth. The standard treatment consisted of 'courses' of injections of arsenical and bismuth preparations—each course being of seven injections of arsenic and bismuth simultaneously, once a week, with interval of about four to five weeks between courses. Total minimum number of courses, for a case, was three. It was appreciated that intravenous arsenic was ideal but intramuscular injections of arsenic were allowed. Gonorrhoea cases were given sulphanilamide group of drugs, urethral irrigations and vaccine if necessary.

Energetic medical officers carried out the post hospital treatment satisfactorily but no regular system was established to ensure adequate surveillance, complete treatment or detect patients failing to turn up for regular treatment. Prevention of venereal diseases included issue of emergency treatment packets and irrigations with potassium permanganate in unit preventive ablution rooms. The latter facilities were, however, not available in Indian units. The areas where infected women were likely to be found were placed strictly out of bounds.

Venereology and dermatology were combined subjects in the India Command and the specialists for these two subjects were called 'dermatologists'. In August 1942, their number was increased to 18 but the difficulty was to find suitable officers to fill the posts. By February 1943, only 12 were filled. The officers were stationed at

Rawalpindi, Lahore, Jubbulpore, Karachi, Shillong, Deolali, Poona, Bangalore, Secunderabad and Colombo (Ceylon). It will be noted that an important centre such as Calcutta had none. In July 1943, the authorised number of specialists was further increased to a total of 64. In January 1944, this was amended to give 40 specialists in venereology and 24 in dermatology. Thus, for the first time in the India Command, venereologists and dermatologists were finally separated and were enabled to devote their entire energies to their respective specialities.

FORMATION OF VENEREAL DISEASE WINGS

It was considered essential for smooth working and increased efficiency that an establishment should be obtained to allow the formation of venereal disease wings which were to be part of a general hospital. A definite policy of regionalised treatment was agreed to. Establishments were provided for Indian venereal disease wing, (Indian and British troops) on 17 February 1944. These establishments enabled the wings to be raised in various hospitals throughout the India Command. As soon as a centre was raised, all cases of venereal diseases were treated in the centre by a trained staff. On the whole, 38 centres with 4,900 Indian and 1,400 British beds were raised.

SERVICES CLINIC, CALCUTTA

In view of the large number of out-patients constantly in Calcutta on duty and on leave, together with the fact that the CMH, Serampore was 15 miles away and not readily accessible, it was decided to establish an out-patients clinic in Calcutta on the lines of a civil clinic. Its functions were : (i) to treat all out-patients in the Calcutta area and (ii) to examine all new patients who reported in the first instance to the clinic for investigation and diagnosis. By these means many patients not suffering from venereal diseases were weeded out before being sent to the hospital.

The establishment authorising the raising of the clinic was obtained in July 1944. The clinic rapidly justified its existence. The average weekly attendance was more than 1,000 patients, all of whom would normally have gone to Serampore.

HYPERTHERMY CENTRE, LEBONG

It was considered necessary to establish a hyperthermy centre for the treatment of certain chronic cases of gonorrhoea and non-specific urethritis. The establishment for such a centre was obtained in June 1945. A trained specialist and nursing sisters trained in the special treatment were available but due to great difficulties and delays in the supply of equipment it was not possible to start the centre. The scheme for establishing this centre at Lebong was, therefore, reluctantly abandoned.

CONSULTANTS AND ADVISERS

Prior to 1943, there was no consultant venereologist or adviser in venereology at the Headquarters India Command and no efficient co-ordination or organisation of venereal disease services in the Indian Army. Patients suffering from these diseases were admitted to isolation wards of almost all the hospitals. No establishment existed which provided adequate specialist facilities and nursing orderlies. The routine work devolved upon the consultant physician, India Command. The adviser in dermatology had this background to contend with when he took over in February 1943. In August 1943, the occupant of the post of adviser in dermatology became the adviser in venereology and separate adviser in dermatology was posted. This relieved the venereologist of a considerable amount of work and enabled him to devote his entire energies to venereology. On 31 October 1944, the appointment of adviser in venereology, was upgraded to that of consultant venereologist, India Command.

In April 1945, after considerable discussion and delay approval was given for the appointments of advisers in venereology to armies and commands. Such appointments relieved the consultant of much supervision work. The most important function of these advisers, apart from clinical work and consultation on cases referred to them, was that of teaching and reporting on the capability of trainees. Recommendations for the posting of personnel and locations of centres and the control of the issue of special equipment, remained the responsibility of the consultant at the GHQ.

RELATIONSHIP WITH THE SEAC

Since the India Command was responsible for the medical services for the forces in Assam and Burma up to the time when an independent command (Eleventh Army Group, afterwards ALFSEA) was constituted, the services of the consultants at the Medical Directorate were also required for these forces until a consultant venereologist was appointed to the latter formation early in 1945. Throughout the campaign, India was responsible for meeting the requirements as regards units, reinforcement of personnel and maintenance of supplies of equipment. During this time venereal disease patients were treated at Imphal, Kohima, Dimapore (Manipur Road), Gauhati, Shillong, Comilla, Chittagong and Cox's Bazaar.

As regards Ceylon, British troops received treatment at No. 35 BGH Colombo and Indian troops in Colombo and Trincomalee. The naval cases were treated at the Royal Navy Auxiliary Hospitals at Trincomalee and Colombo and the Ceylonese at No. 132 Ceylonese General Hospital.

PERSONNEL

By December 1945, 140 specialists and trainees were employed to look after the patients suffering from venereal diseases. These were distributed as follows :—

Specialists and trainees	India Command	ALFSEA	East and West African units
IAMC recognised	13	0	...
IAMC graded	30	8	...
IAMC trainees	27	12	...
Civil medical practitioner graded ...	...	1	...
RAMC recognised	7	8	...
RAMC graded	18	5	3
RAMC trainees	3	4	1
Total	98	38	4

SPECIALISTS

The number of RAMC specialists in 1943 was limited and was made up by training suitable general duty officers late in 1944 and early in 1945. However, some experienced officers were posted from the United Kingdom and from the formations in other places.

The number of Indian venereologists was also small. This was due to two factors : (i) no specialist was available from the regular cadre and (ii) amongst the emergency commissioned officers, due to lack of encouragement of venereology as a separate subject then existing in the Indian universities and lack of facilities in private practice or in government civil service, all with some exceptions were not trained for the work which devolved upon them. Accordingly it was decided to train suitable officers for this purpose and the results more than justified this step. A large number of keen officers were trained and as they gained experience they proved invaluable.

TRAINING

Training centres under competent specialists were organised and intensive training of suitable officers was undertaken. As a result it was possible, often with difficulty, to meet the commitments.

Sufficient number of British special treatment orderlies (STOs) were available to meet the commitments. Prior to 1943 no Indian STOs existed. During 1943, efforts were made to create a new trade of STO in the IAMC. Up to that time one had to rely on untrained and completely inexperienced orderlies and this threw an enormous amount of additional work on the venereologist. Approval was obtained and active training commenced in January 1944. At the close of the war large numbers of STOs were working in all Indian venereal disease wings and a number were placed at the disposal of ALFSEA, pending the establishment of venereal disease wings in that theatre. These Indian orderlies were remarkably keen and worked well. It was most unfortunate that efforts to obtain their advancement were not successful and this caused much discontentment.

OFFICERS COMMANDING VENEREAL DIVISIONS

The principle of officers commanding divisions being either medical or surgical specialists reacted unfairly on venereologists who in certain hospitals had a very large number of beds under their control. A case was submitted to the Finance Department (Defence) who refused to accept it on the erroneous impression that this had not been approved in the United Kingdom. The DMS decided not to press the point, but agreed that in such cases where the numbers justified it, the officer commanding the division would be a venereologist in place of surgeon or physician. Two such appointments were made in the India Command.

EQUIPMENT

A new scale of equipment was drawn up and financial approval obtained, and by 1945 most of the serious deficiencies had been met.

MEMORANDA ON VENEREAL DISEASES

Prior to the arrival of the adviser in venereology, a book entitled *Venereal Disease, Diagnosis and Treatment 4th edition* was published in 1941, and was extensively used. The sections on diagnosis and pathology were reasonably up to date but the treatment section required revision. A small booklet with the title *Notes on the Treatment of Venereal Diseases* was, therefore, published early in 1943 to bring treatment in conformity with recent advances and on its issue copies of the old book were withdrawn. English and Urdu copies of this small booklet were written and distributed to all venereal disease wings for the use of the STOs. Several administrative and technical instructions were also published for the guidance of officers undertaking the treatment of venereal diseases.

MONTHLY RETURN—VENEREAL DISEASES

Though A.F.A. 31 of the army supplied all the figures of admissions for different venereal diseases throughout the India Command, yet it was not sufficient for the consultant venereologist to know the type and the amount of work involved in different venereal disease treatment centres. Whilst it was fully appreciated that paper work should be kept at a minimum, it was essential that some information should be received regularly regarding the work performed in the venereal disease wings and in consequence a monthly report on a specially printed form was rendered in duplicate, one copy direct to the consultant venereologist at the GHQ India and the second through the usual channels. Much valuable information was obtained from this return.

VENEREAL DISEASE CASE CARD

It was felt during the war that the venereal disease card should be carried by the patients themselves during post-hospital treatment

and surveillance, so that they may not miss their treatment and other tests, in spite of quick movement of troops from place to place. Towards the end of 1942, the old and well tried A. F. 1247 was abolished in India and a new form I.A.F.M. 1272 was brought into use as it was convenient to carry it in the pocket. It was, however, entirely unsatisfactory from the commencement and was on the flimsiest paper. The details of records could not be satisfactorily entered on this form. After considerable delays a new war time form was designed, approved and taken into use. It was an improvement on the one it replaced but not nearly so permanent as the original A.F. 1247.

HOSPITAL STOPPAGES AND LOSS OF PROFICIENCY PAY

The fight for abolition of hospital stoppages and loss of proficiency pay commenced in the United Kingdom in 1939 and materialised in 1945. Thus, an iniquitous penalty which could not on any ground be justified was abandoned completely for British troops and partially for Indian troops. In the case of Indian troops for the first thirty days in hospital, no hospital stoppages were realised, though IAFA 55 (hospital stoppage rolls) continued to be prepared and submitted in respect of each patient. This relieved the patients partially but the clerical work of the venereal disease treatment centres, on this item, remained the same without any benefit to the State. It was not possible to abolish the loss of proficiency pay and by December 1945, the case for its abolition was still under consideration.

1945-46.

By the end of December 1945, consultant venereologist's post was terminated. The posts of the adviser in venereology of each command were also abolished. From January to June 1946, all the work of the consultant venereologist was taken over by the consultant physician of the Army Headquarters. It was soon apparent that this arrangement was leading to inefficiency of the venereal disease department. So, in July 1946, the former adviser in venereology of the North Western Army (Northern Command) was brought to Delhi to take up the appointment of adviser in venereology at Army Headquarters, in addition to this work as venereologist of Military Hospital, Delhi Cantt., though the post was not officially sanctioned.

During 1946 beds for treatment of venereal disease cases were authorised in selected hospitals and venereal disease treatment wings were abolished. The authorised orderlies were reduced from one per ten beds to one per fifteen beds and clerks were abolished.

All arrangements were perfected for starting a Central Syphilis Register for British troops only[1]. During the time of the consultant

[1] The Central Syphilis Register for Indian troops was subsequently started in March, 1948 in collaboration with Army Statistical Organisation (Hollerith Department).

venereologist, all the venereal disease cards, after final test of cure, were to be sent to him for perusal. This was stopped on the advice of the consultant physician, thereby relaxing control on the work of the venereologists.

Pre-release treatment of 'non-syphilitic' cases who could not be kept for full surveillance period, with full course of penicillin as for syphilis, was ordered.

TREATMENT AND PREVENTION OF VENEREAL DISEASES.

CLINICAL

From 1943 *Onwards:* Treatment up to 1943 continued almost on the same basis as before the war. An immediate attempt was made in 1943 to bring treatment up to date. The standard treatment of gonorrhoea was sulphapyridine in adequate and regular dosage. As supplies became available sulphathiazole was gradually substituted and the routine treatment consisted of three tablets four times daily for five days. This rapidly led to a shorter period of hospitalisation with a considerable effect on conservation of manpower. In cases of syphilis intravenous arsenic in the form of NAB and similar preparations were taken into use as soon as supplies became available. This together with bismuth constituted the standard treatment of syphilis.

End of 1944 : Towards the end of 1944, limited supplies of penicillin became available for the treatment of venereal diseases. In the first instance, it was decided to use penicillin only in the cases of chronic resistant gonorrhoea. Many of the patients treated—all sulphonamide resistant and complicated cases—had been in hospital for long periods. The results of penicillin therapy were dramatic, a very large proportion of these patients being cured in two or three days. It was obvious that a very potent therapeutic substance had come into being. The situation in regard to supply of penicillin improved rapidly ; within a month it was possible to treat all cases of gonorrhoea with penicillin from the commencement of the disease. The length of stay in hospital dropped from at least twelve days to two days, resulting in a great saving of hospital beds. Within another month or so it was found that the stock of penicillin was sufficient to justify its use in cases of syphilis. At first all early cases were treated and then, gradually, late cases were treated experimentally with increased dosage. The short term results were excellent, but it has not been possible to follow up the cases for a sufficiently long period of time to assess the long-term results. A little later a large number of patients was admitted for penicillin therapy who had been given arsenic and bismuth but who had not completed the course of treatment. These patients included many whose treatment had been irregular on account of active service conditions ; in many other cases neglect on the part of the patient or others had led to this irregularity. Patients with gonorrhoea were treated with 100,000 units of penicillin, given as ten injections of 10,000 units, or five injections of 20,000 units, at three hourly intervals. Patients with syphilis were given 2,400,000 units in 60 doses of 40,000 units every three hours.

A large scale investigation was undertaken in July 1945 to try the effects of different types of treatment in cases of syphilis[2].

On the first day of treatment it was not uncommon for minor reactions to occur, the most frequent being slight fever, although occasionally temperatures up to 105°F were recorded. Such reactions were not an indication for the interruption of treatment, as they always settled down after a few hours. On the termination of treatment the primary sore was almost always healed, and the secondary rash, if present, usually disappeared. In a small proportion of patients, healing of the sore or disappearance of the rash was not quite complete, but further treatment was not considered necessary. Blood tests were taken every two months for six months after the completion of treatment, and then every three months for a further period of twelve months. It should be appreciated that the sero-positivity of blood may take several months to become negative after the completion of treatment depending upon the development of immunity. Persistence of sero-positivity does not indicate failure of treatment unless there is rising serological titre. With the course of treatment outlined, relapses either clinical or serological, apparently occur in 10 to 15 per cent. of patients. Clinical relapses consist of a reappearance of the genital or a mucocutaneous lesion. Many of these cases may have been reinfected. Further treatment in such cases is obviously indicated. Observation on these cases will be required for a prolonged period. Reinfections have to be carefully distinguished from relapses. A cerebrospinal fluid examination is essential in all cases and should, if possible, be carried out after six months, and again after two years and five years.

[2] Full details are available in Medical Directorate, India, Technical Instruction No. 54.
Also see Balbir Singh (1947) Penicillin Treatment of Early Syphilis, *Indian med. Gaz.* 82, 10.
He reviewed case cards of 662 cases of syphilis who were treated with penicillin. Rise of temperature occurred during the first day of treatment in 17·4 per cent. of the cases, it rose above 103°F in nine cases only and came down by the end of 24 hours in all except one case in which it lasted for three days. Cutaneous reaction and pain in the joints and muscle were also observed in a few cases. Reaction was, however, never so severe that treatment had to be stopped. Primary lesions healed in eight to ten days. Rash healed in eleven days on the average. Provocative rise of titre of Kahn units occurred in 47 cases out of 256. Similar provocation was also observed in the Wassermann reaction in 37 out of 270 cases. Provocation was most marked in seropositive primary syphilis if they were not put on arsenic and/or bismuth before penicillin treatment. The titre of Kahn units showed reduction in 54·5 per cent. Similar change in Wassermann was shown by 30 per cent. only. Final seroreversal was, however, quicker in Wassermann than in the Kahn, unlike the initial effect mentioned above. Seroreversal was quicker in those cases of seropositive primary syphilis who were switched on to penicillin after they had 1 to 6 injections of arsenic and/or bismuth; seroreversal took longest time in secondary syphilis. Response to treatment was most favourable in seronegative primary cases. 90·9 per cent. were seronegative on their last test; seropositive primary and secondary syphilis showed 58·5 per cent. and 44·2 per cent. respectively as seronegative on their last test.

No relapse occurred in seronegative primary syphilis. Serologic relapse rate was 3·4 per cent. in seropositive primary syphilis and 4·1 per cent. in secondary syphilis. If the incidence is calculated by excluding all cases observed for less than 113 days (the minimum period during which a serological relapse was observed) the serological relapse rate came to 8·3 per cent. Serological and concomitant clinical relapses were 3·5 per cent. on the same basis. Cerebrospinal fluid was positive in 13 out of 52 cases who were examined six months or later, after penicillin treatment. Serum and spinal fluid were positive in 6 (11·3 per cent.) cases. He attributed the relatively higher incidence of serological relapses and of positive cerebrospinal fluid in seropositive primary cases to the inclusion in the group of a few cases who were not fresh cases of seropositive primary syphilis. They were put on penicillin after they had irregular treatment with arsenic and/or bismuth. (Author's summary).

Chancroid : This was commonly seen in India. It did not respond to treatment with penicillin. The treatment advocated was sulphathiazole 4 g. daily for five days.

Lymphogranuloma Inguinale : This disease, being a virus infection, does not respond to penicillin and was successfully treated with sulphathiazole and fever therapy.

Urethritis—Non-specific: Many patients were found to be suffering from this troublesome complaint. It did not respond to penicillin unless the causative organism happened to be a penicillin—sensitive one. Treatment was by means of sulphathiazole, instillation with CTAB or sephiran, irrigation and fever therapy.

TOXIC EFFECTS OF ORGANIC ARSENICALS

Cases of dermatitis did occur but the numbers were not considerable and did not constitute any serious problem. The availability of penicillin made it possible to ensure that these patients received adequate treatment for their syphilis. This would have been problematical if penicillin was not available. Many of the cases were treated with BAL with, for the most part, entirely satisfactory results.

ENCEPHALOPATHY

This very serious and dangerous complication of arsenical therapy assumed serious proportions in 1943, and the first six months of 1944, among the Indian troops. The mortality rate was about 50 per cent. and the total number of cases reported almost 200. There can be little doubt that encephalopathy occurred frequently in the past when probably the usual diagnosis used to be 'clinical cerebral malaria' or some such inaccurate but convenient symptomatic diagnosis. It has not been possible to arrive at any satisfactory conclusion as to the causation of this serious complication of arsenotherapy, although later work has shown it to be partially due to lack of vitamin B_1. The venereologist in CMH Westridge, Rawalpindi, in 1944, based his experiments on the prevention of this complication, by a schedule of arsenotherapy in which the first four injections used to be given in fixed doses of 0·15 g. of NAB bi-weekly and then reverting to normal doses. In this scheme about 275 cases were treated without any incidence of encephalopathy. But this schedule could not be pursued as penicillin came into use. No conclusions, therefore, could be arrived at, though it appeared very promising[3].

ADMISSIONS TO THE TREATMENT CENTRES

From the accurate returns received in the nine months ending 31 October 1945, it was found that a total of 71,893 patients were admitted for diagnosis and treatment to the venereal diseases treatment centres in the India Command during that period ; of this number British and

[3] See also page 79.

Allied troops accounted for 17,722 cases and Indian troops for 54,171 cases (Table I).

TABLE I

Admissions to military venereal disease treatment centres in India from February to October 1945.

Diseases	Number of patients		Relative percentage		Rate per 1,000 strength*	
	Indian	British	Indian	British	Indian	British
Syphilis	17,087	2,179	31·54	12·30	18·05	11·36
Gonorrhoea	10,012	5,051	18·48	28·50	10·58	26·34
Chancroid	17,070	3,969	31·51	22·40	18·03	20·70
Urethritis	3,250	2,416	6·00	13·63	3·43	12·60
Lymphogranuloma Inguinale	284	332	0·52	1·87	0·30	1·73
Balanitis	473	738	0·87	4·16	0·50	3·85
Phimosis and paraphimosis	169	73	0·31	0·41	0·18	0·38
Genital warts... ...	215	301	0·40	1·70	0·23	1·57
Stricture of the urethra ...	48	13	0·09	0·07	0·05	0·07
†Prostatitis	73	83	0·13	0·47	0·08	0·43
†Epididymitis ...	136	89	0·25	0·50	0·14	0·46
Orchitis	114	37	0·21	0·21	0·12	0·19
Others	5,240	2,441	9·67	13·77	5·53	12·73
Total	54,171	17,722	100·0	100·0	57·22	92·41

*Strength figures—Indian officers and other ranks =946, 751; British officers and other ranks=191, 772.

†Not due to venereal diseases.

From Table I, it will be seen that syphilis was responsible for 31 per cent. of all venereal disease admissions in the case of Indian troops and for 12 per cent. in the case of British troops. Gonorrhoea, on the other hand, was responsible for only 18 per cent. of all venereal disease admissions in the case of Indian troops and 28 per cent. in the case of British troops. Expressed somewhat differently, this calculation shows that in the case of Indian troops there are 1·7 cases of syphilis to every one of gonorrhoea, whereas in the case of British troops there are 2·3 cases of gonorrhoea to each case of syphilis. The explanation for this difference is somewhat obscure, but it is well known that the British soldier frequently made use of prophylaxis (although it was often inadequate) whereas the Indian troops seldom did ; also that the prophylactic packet afforded a fair degree of protection against syphilis but little against gonorrhoea.

TABLE II

Relative incidence of syphilis in the Army in India from February to October 1945.

Stage	Number of cases		Relative percentages to the total	
	Indian	British	Indian	British
Primary	13,852	1,827	81·1	83·8
Secondary	2,600	244	15·2	11·2
Late	635	108	3·7	5·0
Total	17,087	2,179	100·0	100·0

From Table II it will be seen that syphilis reached the secondary stage in 15·2 per cent. of Indian cases and 11·2 per cent. in British cases before the patient reported at the centre. These figures are dissappointingly high. The incidence of secondary cases was due for the most part to the lack of regular medical inspection, although it is quite probable that a certain proportion of the delay in treatment was due to the actual concealment or to ignorance on the part of the patients.

TABLE III

Relative incidence of gonorrhoea in the Army in India from February to October, 1945.

Stage	Number of cases		Relative percentages to the total	
	Indian	British	Indian	British
Fresh	9,125	4,686	91·1	92·8
Relapse	409	266	4·1	5·2
Complicated	478	99	4·8	2·0
Total	10,012	5,051	100·0	100·0

The relapse rate for all patients treated for gonorrhoea with penicillin in the dosage already indicated, as shown in Table III, is 4·1 per cent. in the case of Indian and 5·2 per cent. in the case of British troops, giving an overall average relapse rate of 4·5 per cent. The substitution of penicillin for sulphathiazole as stated above resulted in an immediate reduction in the total number of beds occupied by patients with venereal disease. What was not generally recognised was the enormous concentration of work that also resulted ; consequently, frequent demands for reduction of staff had to be strongly opposed.

The excellent work, often under difficult and trying conditions, performed by the advisers in venereology, venereologists and trainees working in the venereal disease wards, as well as, that of the STOs, deserves the highest praise.

Relative rate of syphilis, gonorrhoea and chancroid in the Army in India and venereal diseases rates per 1,000 by groups are given in Tables IV and V.

Table IV

Relative rates of syphilis, gonorrhoea and chancroid in the Army in India from February to October, 1945.

Diseases	Number of cases		Percentages	
	Indian	British	Indian	British
Syphilis	17,087	2,179	38·7	19·5
Gonorrhoea	10,012	5,051	22·6	45·1
Chancroid	17,070	3,969	38·7	35·4
Total	44,169	11,199	100·0	100·0

Table V

Incidence of venereal diseases (rate per 1,000) *among IORs and BORs in the India Command during* 1939-45.

Years	IORs				BORs			Total venereal diseases
	Gonorrhoea	Syphilis	Soft chancre (including other venereal diseases)	Total venereal diseases	Gonorrhoea	Syphilis	Soft chancre (including other venereal diseases)	
1939	3·4	3·4	1·7	8·5	32·7	8·4	11·9	53·1
1940	7·5	6·1	5·3	18·9	30·9	12·7	14·5	58·1
1941	9·4	8·1	10·4	27·9	33·8	12·6	18·1	64·5
1942	11·0	10·3	21·2	42·5	27·1	9·5	33·0	69·6
1943	11·4	9·5	28·9	49·8	26·3	8·2	29·4	63·9
1944	11·5	12·6	24·6	48·7	31·6	9·4	31·0	72·0
1945	8·2	11·7	23·5	43·4	25·6	11·7	42·5	79·8

APPENDIX A

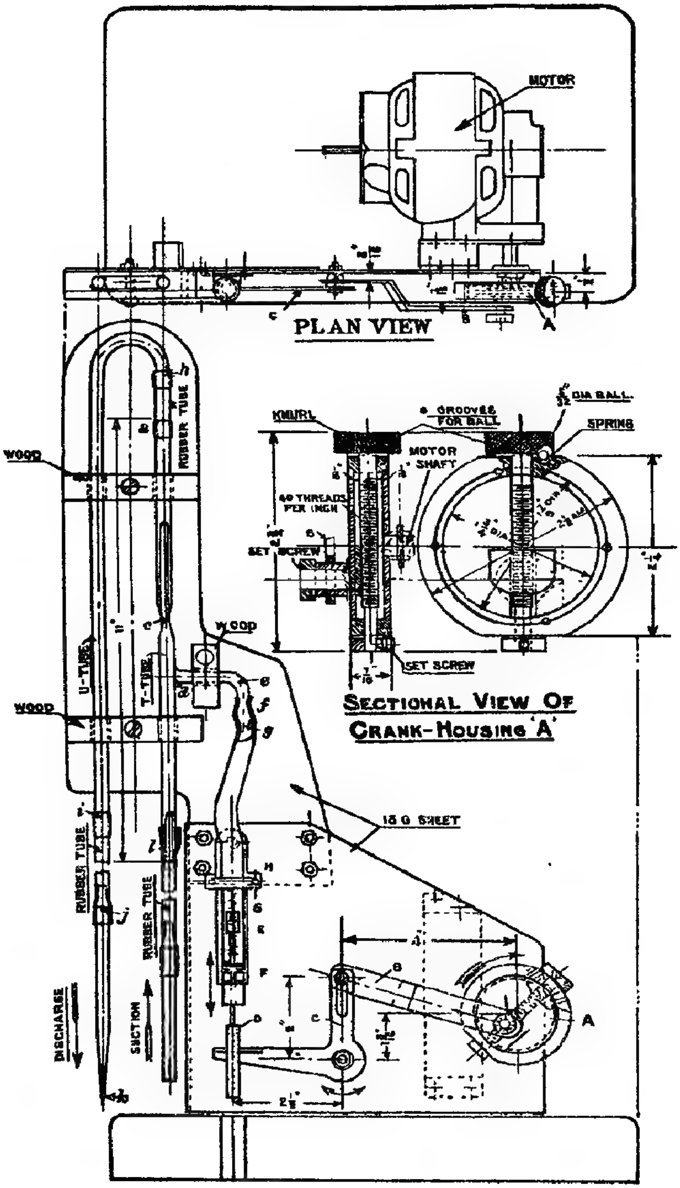
Mechanical Pipette.

The large number of sera received for the Wassermann reaction and Kahn tests and a small number of the technicians provided by the war establishment for a field laboratory were responsible for the development of an automatic pipette worked by an electric motor in No. 24 Indian Field Laboratory which was functioning as a serological laboratory for the Ceylon Army Command during the years 1945 and 1946. It was made out of the materials salvaged from a small workshop as no official sanction was available.

12 cc. to 1 cc. of normal saline could be dropped in 21 tubes in one minute by switching on the motor. It reduced the time in carrying out Kahn test and enabled the pathologist not to depend upon the ambulance sepoys or the sweepers to drop saline into the tubes after the patients' serum and the antigen were shaken. The details of this apparatus were published by Major Balbir Singh IMS/IAMC, who was responsible for its development, in the *British Journal of Venereal Diseases*, Vol. XXV, page 202, 1949.

A MECHANICAL PIPETTE

Plan of apparatus



FRONT VIEW

Courtesy British Journal of Venereal Diseases

APPENDIX B

False Positive Serological Reactions for Syphilis in Malaria.

One hundred and twenty-two cases of malaria were investigated by Major Balbir Singh IMS/IAMC for serological reactions for syphilis. 38·6 per cent. showed Wassermann reaction and/or Kahn tests positive. The proportion of these two tests showing changes was the same but either of the two remained negative in some cases. Corrected positive rate for malaria was 27·3 per cent. as 11·3 per cent. of the hospital population not suffering from malaria had shown Wassermann and/or Kahn tests positive.

The verification tests were carried out in 24 cases who had positive or doubtful Kahn test. Only 8 of these showed reaction similar to that of Lues and Kahn units varied in them from 4 to 40. Titres below four units were associated with a general biologic (false positive) type of reaction.

The temperature at the time when blood was drawn and the type of the malarial parasite had no relation with the serological reactions and they were observed in most cases during the first week of the onset of fever.

CHAPTER XXVII

Anaesthesia

The first step towards any kind of organisation of the anaesthetic services for the Army in India, was taken by the appointment in May 1942 of an adviser in anaesthetics to the GHQ. In 1944, this appointment was upgraded to that of consultant anaesthetist, India Command. The main problems which confronted the adviser and are likely in the event of any future war to remain unaltered, were those of personnel, specialist establishment, equipment and supplies and training.

PERSONNEL

In April 1943, there were only 11 recognised anaesthetists serving in the India Command. In July 1945, there were 216, and the final target to fill all the existing appointments authorised within establishment was 298. Difficulty was experienced in the summer of 1942 in locating trained anaesthetists. This was due to the fact that diversions of units and drafts from Malaya to India and the return of troops who escaped from Malaya, or retreated from Burma, resulted in great difficulty in obtaining nominal rolls until several months had elapsed. The introduction of the form giving a summary of qualifications of all medical officers was a step which was of the greatest possible value not only with regard to anaesthetists, but also in enabling the correct assessment for the best possible disposal of all medical officers, and this could usefully be made into a standard Indian Army Form.

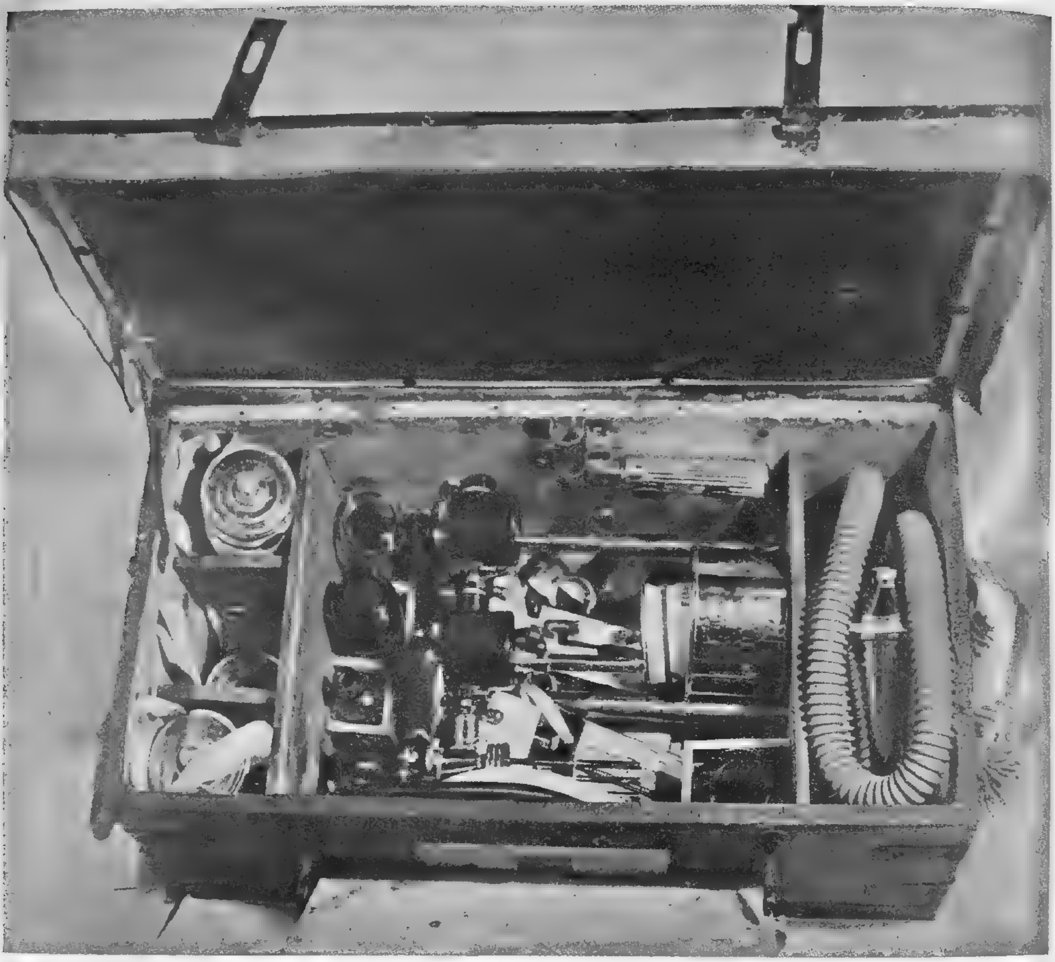
By June 1942, it was clear that the inflow of trained anaesthetists would not keep pace with the rapidity of the expansion of the Army in India. It was, therefore, recommended to, and accepted by the DMS in India that training centres in anaesthesia should be established in each army and command. The training courses were started in August 1942, and functioned continuously until the end of 1945. The system was a great success and, in fact, provided the Army in India and ALFSEA with no less than 151 anaesthetists.

ESTABLISHMENT

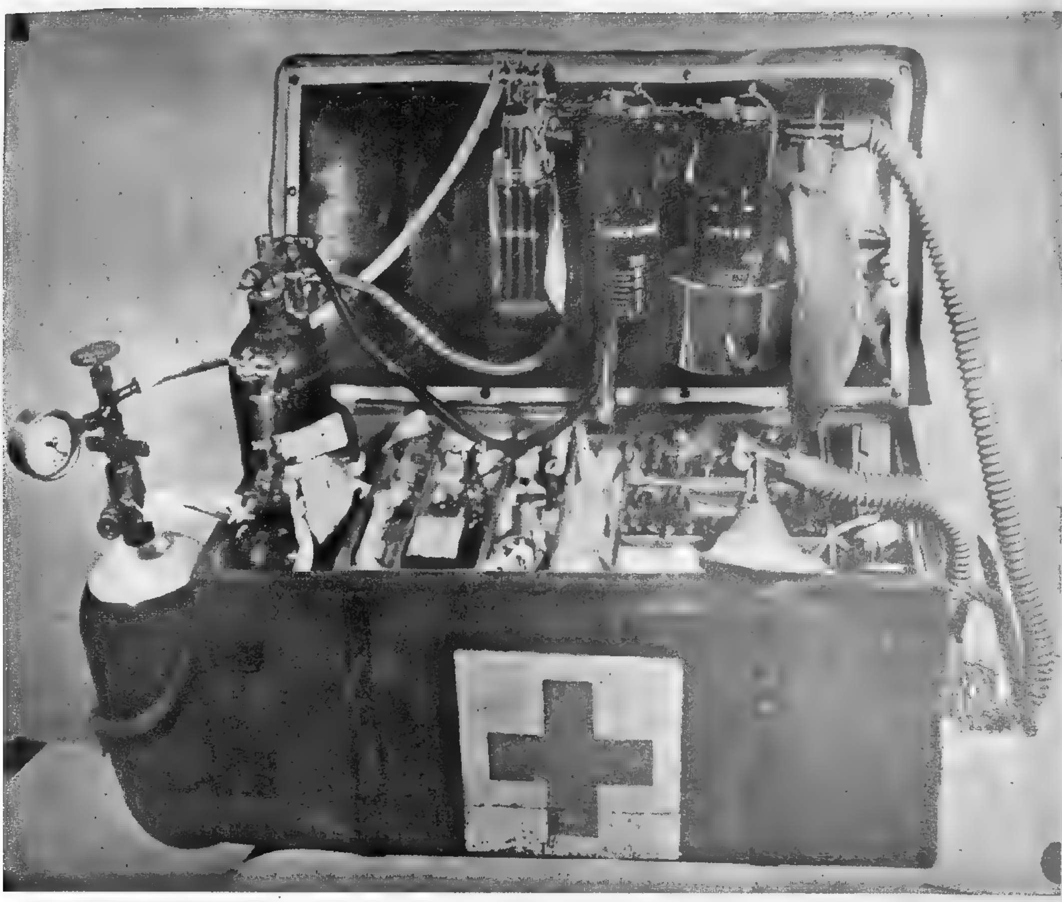
The most useful change in the establishment of units was the authorisation of a specialist or graded anaesthetist in each Indian CCS, and in the newly formed mobile surgical units. In a war of mobility, or which presents difficulties of terrain and communications, it is now accepted that surgical aid should be brought as close as possible to the patient. For this reason, anaesthetists serving in mobile surgical units or in CCSs actively engaged, should be of the highest quality, both physically and professionally. Moreover, in a unit so small as a mobile surgical unit, command of the unit should not belong automatically to the surgical specialist. Command should belong to the officer most suited by seniority and temperament, and

Medical pannier for anæsthetic equipment. (Showing the pannier with the tray carrying syringes, drugs, etc.).

PLATE XVI



Medical pannier for anæsthetic equipment. (Showing arrangements for packing Boyle's apparatus and nitrous oxide cylinder).



Medical pannier for anæsthetic equipment. (Showing the apparatus set up for administration of an anæsthetic).

both in India and in the Middle East, some mobile surgical units were successfully commanded by the anaesthetist, with complete harmony between surgeon and anaesthetist. Anaesthetic specialists in forward units should be relieved whether it is their wish or not, and given a period of rest in a base unit after a prolonged stay (viz., 6 to 12 months) in a forward unit in action. It was noticeable that although many anaesthetists enjoyed being in a forward unit, both physically and mentally they seemed tired after prolonged periods in action in the jungle. There was a tendency, especially in view of the shortage of trained personnel to keep anaesthetists for too long in a forward unit. Another constant problem of personnel was the difficulty of grading trainees and applicants for specialist status. This difficulty, at any rate as regards anaesthesia, was largely overcome by the system which will be later explained under the heading of 'clinical training'.

EQUIPMENT AND SUPPLIES

A survey of the available resources was made in April and May of 1942. The MME scales of all types of medical units were critically examined and steps taken to modernise the anaesthetic equipment and the drugs provided for anaesthesia. This immediately raised a large problem for the Supply Department. To quote one example, nitrous oxide, one of the most important gases used in anaesthesia, had never before been manufactured in India. A plant was established which was capable of producing 750,000 gallons of this gas per week. In 1942, almost every item of anaesthetic equipment and supplies was on the list of controlled items, sanction for issue of which rested with the DMS. By 31 December 1944, all items of anaesthetic equipment and supplies were de-controlled and were in free supply.

The important feature was the remodelling of the Indian mobile surgical units as a result of the experience gained with these units in the Arakan Campaign of 1942-43. A committee met in Delhi, in July 1942, and devised methods to attain more mobility, without in the least detracting from the specialist efficiency, of mobile surgical units. Anaesthetic equipment was designed to be carried in a standard medical pannier, slightly altered in its internal fittings to accommodate the Boyle's apparatus. The pannier was so arranged that breakable parts of apparatus such as syringes and laryngoscope were tightly clamped in metal trays which could be used for sterilisation of apparatus when required. The total weight of the pannier was 58 lbs., and by arranging for the transport of oxygen cylinders in the other pack, the pannier and cylinders became a balanced pack for one mule. Plate XV shows the pannier with the tray carrying syringes, drugs, etc. Plate XVI shows arrangement for packing Boyle's apparatus and nitrous oxide cylinder in the most satisfactory manner for avoiding breakage. Plate XVII shows the apparatus set up for administration of an anaesthetic. It will be noted that a simple canvas sling on one of the ropes of the pannier acts as an oxygen cylinder stand. The full scale of equipment carried in this pannier is described in the MME scale of Indian mobile surgical unit issued in the latter part of 1943. It is

gratifying to record that on one occasion, although a mule carrying one such pannier fell from a height of 70 feet, the pannier and its contents were entirely undamaged.

Another important point in the supply of modern anaesthetic apparatus, is to bear in mind that 'any chain is no stronger than its weakest link', and that a valuable and important piece of apparatus may be rendered unserviceable by a comparatively trivial breakdown, e.g., lack of spare washers for cylinder reducing valves, and that when an apparatus is ordered, care should be taken to order and to distribute among the medical stores, large quantities of parts which wear out with constant use.

In the absence as yet of world-wide standardisation of couplings for medical gas cylinders, it is of the utmost importance that a supply of simple adaptors is available, so that cylinders of different pattern may be freely used. Another important point is that in modern warfare, many air force units are equipped with oxygen supply plants which may be established at comparatively forward air fields. If army medical liaison with the air force is of high standard, it would be possible to arrange for cylinders required by medical units to be filled with oxygen at neighbouring air force supply points. This procedure, which was adopted in the India Command during the last two years of the war, saved time and transport for the supply of oxygen to forward units.

Air dropping of anaesthetic equipment provides another problem which may arise in future warfare. Large quantities of pentothal for intravenous anaesthesia were dropped during the period when the 7th Indian Division was surrounded by the Japanese on the Arakan front. Of the total quantity dropped, 75 per cent. was recovered by the medical units in the 'box'. Oxygen was also supplied by air dropping, and in this connection it should be unnecessary to add that oxygen should always be dropped by parachute, as otherwise the cylinder becomes an extremely dangerous missile to the unfortunate recipients.

Trilene (trichloroethylene) came into use for clinical anaesthesia too late for it to be obtained and used in any large quantities in India during the war. It seems, however, that it is a drug which has advantages in war surgery, particularly in as much as it is non-explosive and non-inflammable. In an age of constant discovery, prophecy is vain, but until some better drug of its nature is discovered, it seems likely that in a future war the anaesthetic equipment of medical units will contain more trilene and less ether, particularly in view of the wastage from evaporation of the latter in tropical climates.

CLINICAL TRAINING

Clinical training was an extremely important feature of the conduct of anaesthesia in the India Command. Apart from being a source of recruitment of medical officers to fill authorised vacancies within establishments as anaesthetists, it was of the utmost

value in assessing the technical capability of officers applying for classification as recognised specialists.

Four training units were started. Officers were attached to the course for one month, during which they were given intensive clinical instructions and a course of lectures. A clinical course was held wherever there was an abundance of clinical material. For example, adviser in anaesthetics to the North Western Army, held courses in Lahore with its greater clinical facilities than could be provided elsewhere in the army. It was made abundantly clear by order, that officers attached to a medical unit for the course, were attached solely for the purpose of training and were not allowed to undertake unit duties. This was of great importance, as there was naturally an understandable tendency for officers commanding medical units to regard attached officers as legitimate additions to the strength for unit duties. Training courses cannot fulfil their primary function unless such state of affairs is effectively prevented by an order from higher authority.

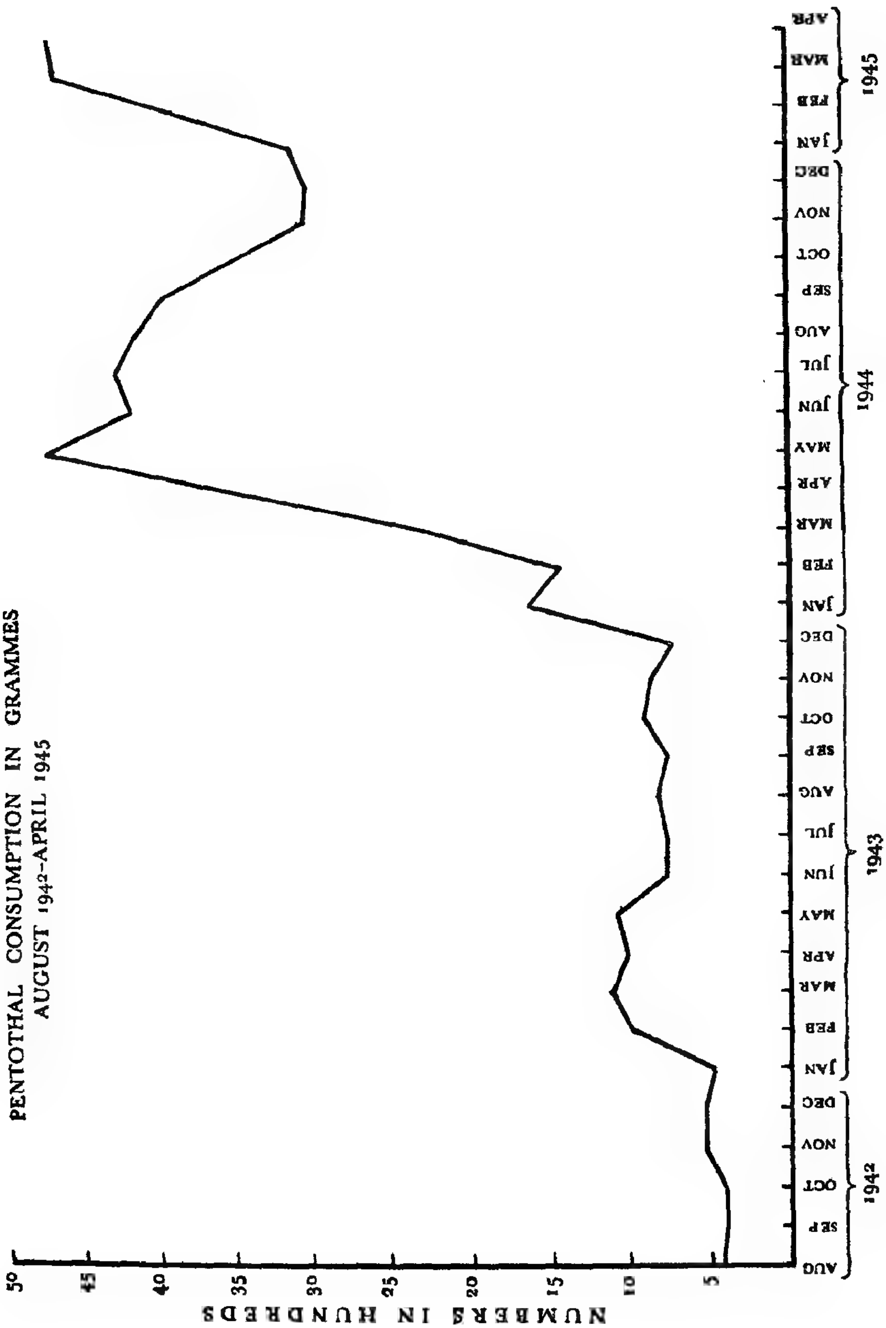
By the summer of 1942, there was a considerable consensus of opinion that pentothal, followed if necessary, by the administration of nitrous oxide and oxygen with minimal ether, was probably the best available method of anaesthesia for battle casualties. The accumulated evidence from all theatres of war now confirms that opinion. Steps were taken to ensure that this method was taught in the training courses, and the value of the lessons so taught is well illustrated by Graph I showing the consumption of pentothal during the period July 1942 to April 1945. The peak period was reached during the battles of Kohima and Imphal in 1944 and the capture of Burma in 1945.

Medical Directorate, India, Technical Instruction No. 41 provides a useful summary of practice of anaesthesia as generally performed in the India Command at that date. The following IAOs dealing with the subject of anaesthesia were also published:—

IAO 384/1943—Administration of anaesthesia.
IAO 1336/1943—Prevention of fire and explosions in operation theatres.
IAO 1388/1943—Medical gas cylinders.

GRAPH I

PENTOTHAL CONSUMPTION IN GRAMMES
AUGUST 1942-APRIL 1945



APPENDIX A

Note by Adviser in Anaesthetics—North Western Army

STATUS OF ANAESTHETIST

In 1942, the status of the anaesthetist in military hospitals was not high, and the duties of a specialist in this field were little realised. However, after the establishment of the four training units, and still more after each of the instructors in these units was empowered to tour the units within their command, a better understanding was reached by commanding officers of units and surgical divisions.

In the North Western Army, through the co-operation of the principal of the medical college in Lahore, the teaching courses were held in the civil hospitals in Lahore, as well as the military hospitals in the cantonment. The impact of teaching modern anaesthetics on civilian hospital practice was interesting and beneficial to both parties. As many students as possible of the King Edward's Medical College were welcomed to the lectures and demonstrations.

EQUIPMENT

In the majority of hospitals in India, prior to 1942, the anaesthetic methods of choice were usually either the open method or the use of local or regional analgesia. By 1944, the majority of military establishments were equipped with simple gas, oxygen and ether apparatus, laryngoscopes, intra-tracheal tubes and a sufficiency of syringes. At the same time the supply of nitrous oxide and oxygen became more readily available and their use was rapidly increased in the civil hospitals as well. In considering the type of equipment suitable for use in tropical climates, it must be remembered that rubber deteriorates rapidly and adequate supplies of rubber spare parts, such as tubing, re-breathing bags, etc. must always be readily available. It is suggested that such equipment, manufactured out of Latex rubber or plastic material, would be more suitable than the recognised 'rubber mix'. It must also be remembered that laryngoscopes without spare batteries or spare bulbs have only a limited life.

ANAESTHESIA IN TROPICAL CLIMATES

The investigations and experiences of all the advisers confirmed the impression that chloroform was no less dangerous in the tropics than in temperate climates, and its almost universal use was solely due to its convenience, economy and the lack of teaching of other methods. The adviser to the North Western Army received a serious complaint that the cost of ether in the Mayo Hospital, Lahore, had greatly increased the cost per anaesthetic. In the prevention of deaths under anaesthesia, cost must not be considered, and abolishing the use of chloroform reduced the death-rate tremendously, as can be proved from the army figures.

Ether can be employed in the tropics with every success. It is essential, however, that ether itself is kept in an ice-box or refrigerator until the moment of use. While actually in use, if the operating theatre is not air-conditioned, the ether container should be wrapped round with a towel, kept moist with cold water, so that by evaporation the temperature of the ether itself is kept below its boiling point.

Sodium thiopentone (pentothal) is a great blessing in tropical climates, especially for short operations, and in combination with regional or spinal methods.

The carbon dioxide absorption technique must appeal in countries where anaesthetic gases are expensive, but unless the operating theatre is maintained at a temperature of about 80°F, overheating of anaesthetic gases will occur if the canister containing the soda lime is close to the patient's face, unless an ice bag is carefully wrapped around it.

STERILISATION

It must be emphasised that the placing of equipment such as syringes and needles, required for intravenous, local and spinal use, in spirit or antiseptic solution is not an adequate method of sterilisation, particularly in hot climates. All equipment used for such purposes should be either boiled for ten minutes, autoclaved or treated by dry heat (150° C. for one hour). It should also be impressed on all hospital personnel that syringes for aspiration of pus or other septic material, must never be used for anaesthetic purposes. A death resulted from the use of such a syringe for a small dose of pentothal, the patient dying some weeks later from haemorrhage of the brachial artery, due to septic erosion. The syringe was sterilised with spirit, after being used for aspiration.

It was emphasised strongly to all post-graduates that they themselves must superintend the sterilisation of their equipment and should check over before use all equipment and drugs likely to be used. It is only in this way that accidents can be prevented, for the human element will enter into the causation of fatalities, even with the most highly trained theatre staff.

CHAPTER XXVIII

Artificial Limb Centre

Soon after World War I, it was realised that war amputees must be provided with artificial limbs and that these limbs must be kept in necessary repairs from time to time. There were very few manufacturing concerns in the country preparing artificial limbs, and the Government placed contracts with them to supply limbs at fixed rates. The limbs were prepared by them to fit the amputees and the payment was made on the authority of the officer commanding hospital stating that a fitting limb had been provided. The main centre was at Bombay and later on a centre was started at Sialkot. These limbs of necessity had to be of varying standards and specifications. For repairs the patient had to be sent to the company which originally manufactured the limb. In 1934, Captain (later Lieut.-Colonel) A. M. Chaudhuri, while on study leave in England, made special study of the subject at Roehampton, and on his return was appointed technical officer for supply of artificial limbs to the military hospital at Sialkot. In Sialkot, he provided accommodation to the contractor for a factory in the hospital. He directed the work of carpenters and mechanics working in the factory, suggested improvements in various mechanical arrangements to the contractor and later on provided even machines for quickening the pace of the work.

Soon after the outbreak of World War II, it was felt that even with all this help, the work was too much for the contractor, and if the quality and quantity of work had to be maintained, the factory must be taken over and run by the State. With this end in view, plans were made for starting an artificial limb centre. A site was selected in Poona in 1943, and with Lieut.-Colonel A. M. Chaudhuri as its director, the factory started functioning towards the middle of 1944. Mechanics were mainly contractor's men then employed by the Government, some carpenters and leather workers were locally enlisted and trained. Organisation and guidance were mainly done by the director with the help of a sergeant who had worked in one of the limb manufacturing concerns in the United Kingdom before he joined the army. This factory supplied almost all the cases of World War II and was functioning in Poona till January 1947. As the main components, wood and metallic, were readily available in Punjab, it was decided to locate the centre at Lahore instead of Poona.

It had been decided, that all the component parts of artificial limbs should be manufactured in India and need not be imported. To start with, parts like joints had to be imported. Manufacturing them on large scale, would have necessarily taken time. Leather which was used in artificial limbs was of indigenous origin, wood used was Kashmir willow which is of a very good quality and most of the metallic components were prepared in No. 502 Command Workshop, Chaklala. This

Preliminary draft narrative was prepared by Major M. S. Vaidianathan, AMC.

factory was not only supplying artificial limbs but also all other orthopaedic appliances such as surgical boots, boots for foot drop, knee cages and walking calipers, etc.

With the meagre supplies of specialised equipment and machinery available in India, an artificial limb centre was set up again in Poona in February 1948. As most of the components of artificial limbs had to be imported, this factory naturally took some time before it could start taking in cases. By August 1948, the factory could take in almost all types of amputees, and provide them with suitable artificial limbs.

TRAINING

The limbs as stated above, were manufactured by various manufacturing concerns who had made some attempt to understand the mechanics of artificial limbs and trained some artisans in the manufacture. They did not usually employ any trained medical staff and therefore, no progress could be made. Colonel Chaudhuri by bringing the factory into the hospital got the mechanics interested by explaining how the limbs function. These mechanics formed the nucleus staff of the artificial limb centre. In 1944, when new carpenters, leather workers, etc., were recruited, they were trained by these mechanics under the guidance of Colonel Chaudhuri. In 1945, when an IGH went to the United Kingdom, two medical officers from that hospital were detailed to Queen Mary's Hospital, Roehampton for training in artificial limb fitting and manufacture. In India, in 1944, it was realised that it may be difficult to run the army limb centre entirely with civilians. Twelve havildars of the Indian Electrical and Mechanical Engineers (IEME) Service (carpenters, joiners, fitters and leather and fibre workers) were sent to the United Kingdom for training in manufacture of artificial limbs. They returned to India during 1946-47 after completing their training. Three surgical specialists were selected in 1946 for training in artificial limbs. They received a month's training in Artificial Limb Centre, Kirkee and later received further training at Queen Mary's Hospital, Roehampton. Attempts were also made to interest amputees in the production of artificial limbs.

MATERIALS USED IN THE MANUFACTURE

Soon after the outbreak of World War II, it was realised that India can expect only a minor portion of the requirements of artificial limbs from the United Kingdom. It was, therefore, decided that indigenous products would be used and that India must be independent of the imports. Luckily Kashmir willow, which was available in sufficient quantity could replace it. As willow takes quite a long time for seasoning, some English willow had to be imported. But in all long term planning no provision was made for import of this commodity. Suitable types of leather were also available in India to prepare the necessary harness for artificial limb. To start with, the contractors produced metallic parts, e.g., joints in local factories. But as the material used by them was not to the specifications required,

the joints did not last long. It was, therefore, decided to get these parts manufactured in IEME workshops. By 1946, almost all metallic components, required for fitting lower limbs amputees, were manufactured in the Command Workshop, Chaklala. For arms cases all components for dress arms were manufactured at Chaklala, and by 1947, even a satisfactory mechanical elbow had been prepared by them. It will be seen that import of a very few items was required for the manufacture of artificial limbs.

In the later part of 1944, when the contractor failed to produce sufficient quantity of component parts required for making limbs, great help was received from Lady Mountbatten, then Superintendent of the British Red Cross Society. She visited the Artificial Limb Centre, Poona to get in touch with the amputees who lost their limbs on the Burma front. She appreciated the difficulty and approached the Secretary of State for India, the War Office and finally the Prime Minister of U.K. and succeeded in securing component parts of 1,000 assorted limbs.

The director of the limb centre had to devote a fair amount of time and energy in training young military surgeons for the right type of stumps required for fitting and for the proper site for various types of amputations that were essential for good fitting.

BELOW KNEE LIMBS

The limbs supplied were triple bearing wooden limb and compared very favourably with the limbs supplied to such amputees in other countries. Officers with these limbs from the centre have played tennis without anybody noticing that they had an artificial limb. The average weight of the limb is $4\frac{1}{2}$ to 5 lbs. It may be added that for tropical countries the wooden limb is preferable to metallic limb, though metal limb is slightly lighter. Up till now, no perspiration-resisting paint has been evolved which will prevent corrosion of metal by perspiration.

ABOVE KNEE LIMBS

The above knee limb is a tuber bearing pelvic suspension limb with slight modifications for shorter stumps. The leather socket was used in the beginning but later it was replaced by willow. A knee lock was considered essential. The central knee control was supplied in selected cases. Pelvic suspension was the standard mode of suspension.

THROUGH HIP LIMBS

Only tilting table pegs were supplied as shaped limbs were heavy.

ARMS CASES

All the upper limb cases were fitted with dress arms till 1946, when an effort was made to manufacture and supply mechanical arms to

patients. Below elbow cases could be easily fixed with mechanical appliances and certain special mechanical appliances, e.g., writing hand, typing finger, 'C' hook etc., were supplied. Mechanical elbow had been manufactured but not fitted in 1947. Since then mechanical elbows of British manufacture have been fitted to above elbow amuptees.

CHANGE OF REGULATIONS

Regulations made in 1921 authorised supply of artificial limbs to all amputees, whose amputation was attributable to service. During World War II, these regulations were further liberalised, i.e., in the case of soldiers [(including VCOs and NCs(E)] the initial provision of the appliances in both attributable and non-attributable cases was undertaken by the Government and the cost met from public funds. In the case of officers requiring artificial limbs or surgical appliances, the cost of provision thereof was met from public funds only where the injury was regarded as attributable to or aggravated by military service. Repair and maintenance of these limbs also were authorised to cases attributable to service. The same principle governed the supply of all other surgical appliances. The centre did not exist long enough to calculate the age of artificial limbs.

CHANGE OF COMMAND

As stated above, the centre was started by medical services. After a few years it was felt that as most of the work was of a mechanical nature, a mechanical engineer would be better suited to administer the centre. The IEME officer, who returned after training in the United Kingdom, was placed in charge of the centre. Subsequently it became apparent that medical and mechanical aspects were both important.

LEGISLATION

Provision of artificial limb is not all that an amputee expects from the State. He is not only to be provided with a limb but he has to be rehabilitated. Rehabilitation, technical and general is given to all amputees while they are being fitted. But to find employment for these rehabilitated amputees is beyond the scope of the army. Legislation must sooner or later be introduced in this country, making it compulsory for factories to employ a certain number of these amputees.

CHAPTER XXIX

The Blood Transfusion Service

INTRODUCTION

Even before the outbreak of World War II, the importance of a blood transfusion service in modern warfare had been realised in India. Attempts to establish station blood transfusion services were encouraged. The importance of a fully organised service as part of the peace time medical organisation, however, had not been recognised and no attempt to develop a co-ordinated blood transfusion service was made till 1942, when the Japanese invasion of India became imminent.

The first transfusion unit in India, No. 1 Indian Base Transfusion Unit was raised in March 1942, with an establishment of two officers, one BOR of the RAMC, ten Indian personnel of the IHC and three attached RIASC personnel. This unit was earmarked for service in Iraq where it arrived on 29 April 1942. It was returned to India in 1944, and joined No. 3 British Base Transfusion Unit in Poona.

In 1940, orders had been issued for the blood grouping of all army personnel. In some military stations, a blood transfusion service was also started. Shortage and unsuitability of equipment and lack of trained personnel, however, resulted in much delay and disappointments. Of the blood collected a great deal was contaminated or became so very soon after collection. Despite many difficulties some district laboratories processed the blood for use in form of plasma and serum. These laboratories did very valuable work when there were no other transfusion facilities available.

In view of the inability of Indian sources of supply to provide the necessary equipment, small scale local blood transfusion schemes appeared to be the only immediate solution to a difficult situation. These schemes were tried but could not meet the demands of the armed forces. Some organisations, however, displayed undoubted efficiency and obtained very promising results. It was, therefore, decided that an army blood transfusion service should be started immediately under the control of the pathology department of the Medical Directorate.

On 9 April 1942, detailed orders regarding the constitution and development of an army transfusion service for India were issued to all headquarters and to all medical units in India. These orders stated clearly that "although there are several civil centres already established, there is no military organisation in India for the purpose". It outlined the objects of the scheme in the following words. "The dissemination of knowledge of transfusion from the clinical aspect, as well as the technical side, takes foremost place in this scheme. Until stocks of plasma or serum are available, whole blood will have to be used. Apparatus for the giving and taking of blood is being issued to units. Apparatus for processing plasma or serum will, it is anticipated, soon be available.

Local production of plasma or serum is the second main objective ". This was to be carried out by deputy assistant directors of pathology (DADsP) in-charge of district laboratories. The emphasis was placed on a change of tempo rather than on a change of policy.

Orders were issued requiring the appointment of resuscitation officers in every medical unit, and their training by DADsP by 22 June 1942. Thereafter, these officers were responsible for the organisation of resuscitation centres in their units, and for training of unit personnel, medical officers, nurses and orderlies in resuscitation duties.

Soon after, however, two British base transfusion units with their associated field transfusion units were made available to India. The first of these, No. 2 Base Transfusion Unit arrived in India on 22 June 1942, and was located with No. 3 IBGH. No. 8 Field Transfusion Unit also arrived with the base transfusion unit. No. 2 and No. 5 Field Transfusion Units arrived from the Middle East at about the same time. Their arrival altered the situation, and discussions were immediately instituted to decide what alterations in the existing scheme would be made on the arrival of the second base transfusion unit with its attached field transfusion units. Shortly after, No. 3 Base Transfusion Unit arrived in Poona, which became its permanent headquarters. On 11 January 1943, No. 2 Base Transfusion Unit moved to Dehra Dun. It was to cater for North India, while No. 3 Base Transfusion Unit was to cater for the requirements of South India.

TRANSFUSION SERVICE—1942

The base transfusion units commenced the production of salines as soon as equipment was unpacked. In the beginning production was limited by the output of the stills and the number of bottles. The officers commanding in their capacity as advisers to the DDsMS of their areas, toured extensively inspecting the blood transfusion arrangements throughout their areas and making recommendations for improvement wherever necessary. Thus, the officer commanding No. 2 Base Transfusion Unit had by the end of 1942 spent 5½ months away from the unit, of which 2½ months had been spent on tour during which he covered nearly 17,000 miles by rail.

PROCUREMENT OF BLOOD TRANSFUSION EQUIPMENT

Scales of blood transfusion and resuscitation equipment were drawn up for the following medical units :—

Field ambulances.
Casualty clearing stations.
Staging sections.
Indian general hospitals.
Hospital trains.
Hospital ships.
Garrison military hospitals.

Equipment could neither be obtained from the United Kingdom unless it was on a financially sanctioned scale, nor was such equipment

procurable in India. It was, therefore, necessary to include all transfusion and resuscitation equipment in the Priced Vocabulary of Medical Stores (PVMS) and to review production resources in India. Section 27 of the PVMS was based on the British equipment scale and financial sanction was obtained for this scale in August 1943. Orders were then placed on the Supply Department.

Officers of the transfusion service were in constant communication with the Supply Department and with various firms in India concerning the production of equipment but progress in this sphere was extremely slow.

The amount of transfusion equipment, which had been brought from the United Kingdom by the units, was completely inadequate. Supply of the smallest parts was difficult even after utilising a certain amount of transfusion equipment originally issued for Burma and Malaya. At first the equipment had been designed for a unit working in very close contact with the parent depot at Bristol. Later the parent depot was some 6,000 miles away by sea at a time when ships were few and convoys were suffering heavy losses. Also the depot at that time was heavily committed in supplying units engaged in heavy fighting in the Mediterranean area. As it was evident that the apparatus must be obtained as rapidly as possible it was decided that the original pattern of the British blood transfusion set should be retained. The necessary alterations were made in the packing of the equipment and transfusion fluids. Packings were chosen which were thought to be more suited to transport facilities likely to be available in the jungle.

FIELD TRANSFUSION UNITS

Towards the end of 1942, No. 2 and No. 3 Field Transfusion Units moved forward to Imphal and Cox's Bazaar, respectively, covering from these bases the supply to the army formations in Assam and Arakan. These were mainly the IV Indian Corps units in Assam and XV Indian Corps units in Arakan.

TRANSFUSION SERVICE—1943

The first few months of 1943 saw slow progress in the development of the transfusion service. The delay resulted from difficulties in securing adequate accommodation, inadequacy of personnel and shortage of equipment. The difficulties encountered in the provision of accommodation were common to all similar projects throughout India at the time. It was not until two months after their arrival that the base transfusion units were able to commence work even on a small scale. Transfusion units were hard pressed by shortage of personnel. The raising of two Indian blood storage units for attachment to each base transfusion unit was, therefore, authorised.

INDIAN ADVANCED BASE TRANSFUSION UNIT

Lines of communication were very long. Areas to be covered were vast and supplies had to be delivered safely and speedily. A new

type of unit was considered essential to act as an intermediate link in the chain of supply between the base transfusion units and the consuming units such as field transfusion units and other medical units in the field. This work had been undertaken by field transfusion units in Calcutta and Bangalore, but it meant that these two units were thus unable to fulfil their proper role.

The raising of two Indian advanced base transfusion units was, therefore, sanctioned. These units were raised from No. 5 and No. 28 Field Transfusion Units in Bangalore and Calcutta, respectively. The war establishment of the advanced base transfusion unit allowed two medical officers, two BORs RAMC, two havildars IAMC, ambulance sepoys, nursing sepoys and drivers. The unit was intended to act as a forwarding unit for supplies of transfusion fluid and apparatus manufactured at the base units. In addition, the advanced unit collected blood from donors, made small quantities of saline solutions and held training courses. The creation of these two units released two field transfusion units for work in the field.

EQUIPMENT

In January 1943, blood transfusion equipment consisted of approximately hundred new items together with two hundred components accounted for in other sections of the PVMS. At the end of that month specifications for all new items were submitted with their current costs to the Chief Inspector of Medical Stores. By the beginning of February, 131 samples of various pieces of transfusion equipment had been made by 65 firms. Operational orders had been placed with 14 of them. No order was placed on any firm whose sample did not conform to the required standard. As many firms as possible were utilised in order to reduce production time to a minimum. Constant visits were paid to manufacturing firms to advise them about the equipment which they were asked to produce.

In spite of persistent efforts to stimulate and maintain production of a satisfactory standard of equipment, delays and disappointments resulted for the following reasons : Special permits had to be obtained from various Directors of Production before orders could be placed for items requiring any of the materials, viz., calico, stainless steel, tin plate, silk and rubber. Many firms when asked to submit estimates took an exceedingly long time to put on paper their prices and production rates. Even after the placing of orders several firms failed to produce bulk material of the same standard as their original samples. No less than eight complete orders were rejected on this ground by February 1943. Sporadic air raids on Calcutta in December 1942 caused certain firms to close down. An order for rubber tubing placed on a firm in Calcutta was, therefore, transferred to a firm in Sialkot, which in turn also failed to produce the material owing to inability to procure transport to bring the rubber from Bombay. In Bombay no firm could be found capable of making suitable rubber tubing. Finally, even when production was achieved the production rate of certain essential items was extremely slow. This was particularly so in the case of transfusion

needles and glass beads, the total output of the latter being ½ oz. per day for every man employed in its manufacture.

In spite of these difficulties and delays, by September 1943, satisfactory indigenous apparatus sufficient to assemble the following number of complete sets had been received by the transfusion units:—

Blood and saline giving sets	1,360
Blood taking sets	1,969
Plasma giving sets	540

But for the slow production of transfusion needles, cannulae and glass beads, it would have been possible to assemble the majority of the sets that had been ordered. Efforts to promote the manufacture of refrigerators, similar to Hall type C-Refrigerators, were unsuccessful and the year closed with shortage of equipment prevalent in many areas.

TRAINING

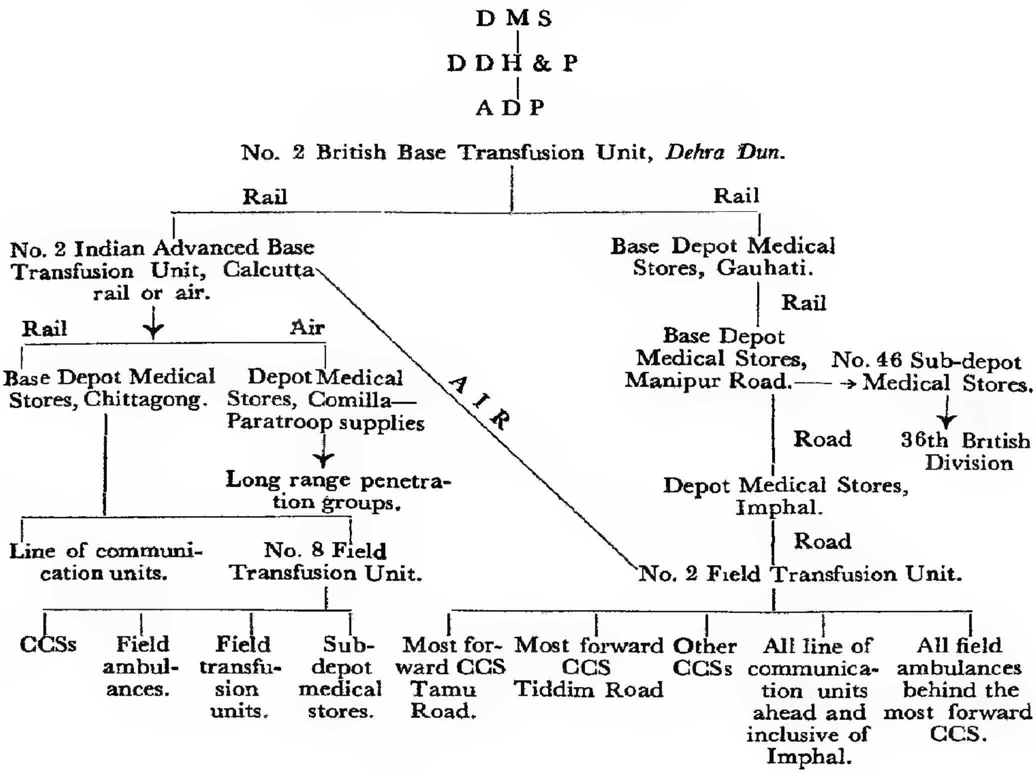
This period of delay due to lack of equipment was fully utilised in running courses of instruction. The first of these courses commenced on 5 July 1943, and they were continued throughout the period of the war. Officers from various units and hospitals were given five-day courses of intensive training in the duties of unit resuscitation officer. Courses for orderlies and members of the WAC(I) were also started and were continued in No. 3 Base Transfusion Unit throughout the war. Courses for medical officers were run by both No. 2 and No. 3 Base Transfusion Units. The courses by No. 2 Base Transfusion Unit were run alternately in Dehra Dun and Calcutta.

ORGANISATION AND ROUTES OF SUPPLY

The following organisation was developed, during 1943, to cover north western, central and eastern India, including Assam and Burma.

Arakan : Blood was collected from local troops by No. 8 Field Transfusion Unit. Arrangements were made for this supply to be augmented if necessary with stocks sent by air from Calcutta to Maungdaw. The latter route was only to be used in cases of great emergency as it was undesirable to send unescorted planes so far forward and it was in fact never required in 1943. Plasma and crystalloidal solutions were obtained by all field units forward and inclusive of Cox's Bazaar from No. 8 Field Transfusion Unit or No. 15 CCS, the maintenance of their stocks being the responsibility of the unit transfusion officer. He in his turn obtained replacements from a dump established at No. 68 IGH, Chittagong. Supplies were sent from Calcutta to Chittagong by one of three routes—rail, river and air or sea. With the onset of the monsoon, fighting in this area came to a virtual standstill. No. 8 Field Transfusion Unit was, therefore, withdrawn for several months in order to give the personnel a change and to help the understaffed base transfusion unit to prepare for the 1944 campaign.

Transfusion service organisation and supply chain (Assam and Arakan) December 1943 *to June* 1944.



Assam : All units forward and inclusive of Manipur Road obtained their supplies from No. 2 Field Transfusion unit which in its turn obtained items of a non-emergency nature direct from Dehra Dun, and all urgent equipment by air from Calcutta.

Bengal : All hospitals in Bengal obtained their supplies from No. 28 Field Transfusion Unit. Plasma was issued to those situated east of the Brahmaputra. This issue was low in order to reserve stocks in case hostilities developed on a very much larger scale. Replacements were forwarded when the amount was reduced by half. Empty bottles and used sets were returned to Calcutta, at the same time as the indent for replacement was submitted. Hospitals were held responsible for maintaining their own panels of donors. It was not possible to institute blood banks because the number of refrigerators available was small. The hospitals were also responsible for preparing glucose saline. A 'still' was sent to each of those hospitals which reported such a deficiency. Chemicals were issued in the form of 60 cc. ampoules which made up the standard isotonic solutions when added to two pints of distilled water. For medical emergencies, such as outbreaks of cholera and severe dysentery, special dumps of crystalloids were established at all base depot and depot medical stores throughout Assam and Arakan.

In February 1943, of the 29 units in Arakan and Assam visited by the officer commanding No. 2 Base Transfusion Unit, only four had not received an issue of plasma or serum; a stock of 300 bottles was available in Arakan and 36 bottles in Assam, giving sets having been issued in the proportion of one to two bottles of plasma. There were chemicals or solutions available for preparing 84,500 bottles of isotonic glucose saline and an issue of dried serum had been supplied to the bomber and fighter squadrons in Bengal. By December 1943, every unit possessed adequate stocks of transfusion fluids and equipment.

GROUPING SERUM

Very soon after the base units were established, it was realised that it would be advisable for them to take over the preparation of all grouping sera for India and Burma. This had been done in the district laboratories previously, and it had been noticed that there was a great variation in the technique of preparation and titration. Some laboratories were filtering the serum but other laboratories did not hav ethe Seitz filters to do this. Some of the serum was prepared with the addition of dyes as antiseptics. For these reasons, the preparation of grouping serum was centralised at the base transfusion units.

ASSEMBLY OF APPARATUS AND PRODUCTION

The initial supplies of transfusion apparatus brought out with the units were assembled and issued to units on a very careful scale of priorities. As soon as indigenous production started, apparatus was assembled and issued to units. This had been continued until all units previously raised and new units had been equipped and maintained on these scales.

Additional commitments had arisen in the equipping of all squadrons, station hospitals, mobile field hospitals and other units of the RAF and Indian Air Force. The requirements of the RIN were also met but they were relatively small.

It was evident that transfusion fluids and equipment must be packed in easily handled and readily recognisable boxes. In view of the difficulties under which many medical units in the field used transfusion equipment, standard packed boxes were developed which contained a fixed proportion of different fluids. This enabled a unit to divide the available stocks very easily between different sections and had the additional advantage that medical officers and orderlies could rely on finding the same fluids in the same type of box.[1]

These boxes were :—

Box, infusion supply pattern, stanpack complete ...	P.V. 27102
Box, wooden, 14 partitioned, empty	P.V. 27111
Box, Indian field transfusion (1942 pattern) ...	P.V. 27140

[1]See also Appendix B.

PRODUCTION OF CRYSTALLOIDS

The production of salines was started as soon as the units were able to get their equipment unpacked. At first the production was very small and was limited by the output of stills and the number of bottles which were available. The output of the saline gradually increased with the improvement in the supplies of stills and bottles.

BLOOD

It was obvious from the very outset that the great distances, the difficulties of transportation, the scarcity of refrigerators, the lack of suitable ice boxes and similar factors made it impossible to attempt a distribution of blood from the base transfusion units.

Every medical unit was instructed that it must make the maximum effort to meet its needs in blood by the formation of local donor panels and local bleeding centres. Like other medical units the field transfusion units also attempted to meet the demands for blood of the neighbouring units.

The base transfusion units started to collect blood from all available donors and supplied blood to the hospitals in their immediate vicinity. The surplus blood was used in the preparation of wet plasma.

BLOOD DONORS

During the year 1943, 5,607 donors were bled by No. 2 Base Transfusion Unit, of whom 900 were Europeans and the remainder Indians and Nepalese. As many of the donors were slightly built, only three quarters of a pint was collected from many of them. No donors were bled until May owing to the lack of refrigerators. Collection of blood was started soon after two small household units were made available. Of this blood 93 pints were issued to local hospitals, the remainder was utilised in the preparation of wet plasma. At No. 2 Advanced Base Transfusion Unit 4,775 donors were bled. Of this blood 150 pints were citrated and issued to local hospitals, the remainder was sent to the Calcutta Blood Bank for the preparation of serum. No. 2 Advanced Base Transfusion Unit also collected 7,565 service donors, and arranged for the Calcutta Blood Bank bleeding teams to collect their blood. At No. 3 Base Transfusion Unit, Poona 7,713 donors were bled. The total number of donors bled by the three units in 1943 thus amounted to 20,053.

Most of the blood taken by the base transfusion unit was used for the preparation of wet plasma. At first the alkali wash method was used but later a change was made to the alkali-CO_2 method. This proved to be moderately successful. Initial difficulties were experienced with the use of seven small 14 cm. Seitz filters. It was not until the beginning of 1943, that it was possible to obtain pilot filters. With the small 14 cm. Seitz filters the maximum amount which could be prepared in one run was 30 pints, but even with this the filtrate showed a tendency

to clot. The use of the pilot filter made a great difference to the total production.

To reduce the risk of contamination, it was arranged that the plasma processing room should only be reached by walking first through the main laboratory and then the blood separation room. The plasma room was sprayed with 10 per cent. chlorosol solution about two hours before the work commenced, whilst the floor was washed down with a 2 per cent. solution of phenol. The plasma was first clarified by drawing through approximately three inches of paper pulp, negative pressure being effected by a hand pump. As a general rule plasma was siphoned off from seven day old blood and clarified in the morning, the processing being carried out in the afternoon. It was passed through the filter at a pH of approximately 10·4 and was brought back to a pH of 7·4. Sterility tests were performed at the beginning, middle and end of each session. They acted as a check on the bacterial content of the atmosphere and on the efficiency of the pads and operators. All the plasma thus prepared was stored in dark warm cupboards where the temperature never exceeded 106°F for a minimum period of three weeks, after which bottles were checked individually and the suitability of the batch considered. Plasma was invariably checked by the officer-in-charge of the laboratory. No doubtful bottle was ever sent to the plasma store. Bottles were always rechecked immediately prior to issue.

The keeping properties of wet plasma in the hot weather was a point which gave rise to some anxiety at first. Some of the bottles which were despatched by train in the hot weather to the forward units seemed to develop lipoid deposits very readily and these were weeded out at Calcutta. The demand for wet plasma was such that the stocks had little time to degenerate in storage as they were issued soon after they were considered fit for issue after the customary period of three weeks.

TRANSFUSION SERVICE—1944

Increasing demands were placed upon the transfusion service during the year 1944. The increased establishments, the improved accommodation and the enhanced production barely enabled the organisation to keep pace with developments.

PERSONNEL

In August, the re-organisation of base transfusion units on a new establishment was authorised but the manpower shortage made it impossible to authorise the sliding scale increase for additional armies and corps. This was a great handicap, especially as several months elapsed before the units could be brought to their full strength in men and vehicles. Furthermore, the new personnel were quite inexperienced and took some time to learn their specialised duties.

In July 1944, the appointment of an ADP (Transfusion) was created at GHQ. He was responsible for co-ordination of the work done by the different transfusion units so that the demands made on the service

by medical units could be evenly distributed, and for the disposal of the rapidly increasing administrative work of the blood transfusion services.

By the end of the year, the base transfusion units, which had arrived in India with a total strength of thirteen, had a working strength of six officers and sixty other ranks (including attached personnel). All of these and more were required to keep pace with demands and it was not possible to build up satisfactory reserves of supplies against future operational commitments.

In August 1944, sanction was obtained for the raising of No. 3 Advanced Base Transfusion Unit in Bangalore. Some increase in the staff working with the advanced base transfusion units was sanctioned during the year as can be seen from the following figures from No. 1 Advanced Base Transfusion Unit.

Period	Average number		
	Officers	BORs	IORs
January to June 1944 ...	2·3	5·0	7·6
July to December 1944 ...	2·5	6·5	11·0

This staff was, however, inadequate to enable the unit to deal with demands received from the Assam, Burma, and Arakan theatres.

ACCOMMODATION

The increased size of the base transfusion units and the increasing demands placed upon them resulted in considerable increase of the accommodation required so that alterations and constructional work interfered with production throughout the year. Extra refrigerators and air-conditioning plants were installed in the plasma processing laboratories and proved invaluable. The delay in installing them, however, was extremely trying and at times actually held up production.

Great difficulty was experienced in securing adequate and reliable water supplies and electricity. Water supplies were insufficient and tended to fail at intervals with resulting difficulties in the operation of distilling plants.

The unreliability of electricity at both base units made it impossible to use this as a source of heat. Heating by Primus stoves proved to be a most inefficient method and was rendered even more ineffective by the poor quality of the stoves available. It was necessary to employ one man on whole time duty to look after them and another man to repair them.

EQUIPMENT SUPPLY

The emergency method of personal contact with the manufacturers adopted in 1943, had to be abandoned in favour of the standard procedure of procurement. This proved to be unsatisfactory. The year had

opened with a universal shortage of transfusion apparatus. This appears to have been due to the fact that no large scale bulk order for any equipment had been placed in the United Kingdom or with any firm in India since August 1943, when the emergency procurement methods had to be abandoned. Why this should have been so is not clear as financial sanction had been obtained which permitted not only the placing of large orders but also their extension to firms in the United Kingdom. To remedy this, demands for all items were subsequently made operational even when the item could be produced in India. The completion date of 31 March 1944 was insisted on in the majority of instances. As a result of these decisions, certain sections of the Supply Department refused to place such orders on Indian firms, because it was stated that they may not be able to complete their contracts in the stipulated time. Many orders which could have been divided between India and the United Kingdom were, therefore, placed in their entirety on the United Kingdom, where it was no longer possible to increase industrial output of equipment required for the transfusion service. Supplies from the United Kingdom proved to be unsatisfactory. The demands from Europe were given high priority. Only surplus stores could come to India. The stores which could be despatched overseas suffered the risk of being lost through hostile action. Consequently, few of the orders placed were supplied during this year. Similar difficulties were experienced in getting the requisite number of refrigerators.

Throughout the year, therefore, output and issues were restricted by the lack of equipment and at no time was there any reserve of the essential items. This was specially so with chemicals, needles, bottles, and important equipment like pilot filters. In many cases, production was delayed until small stocks of certain components became available.

BLOOD DONORS

During the year, 10,145 donors were bled by No. 2 Base Transfusion Unit, of whom 9,095 were Indians and Nepalese, and remaining 1,050 were Europeans. In all 845 pints of blood were issued to hospitals, the greater proportion being despatched by rail to the hospital centre at Lucknow. The remainder was used for the preparation of wet plasma. At Poona 10,554 donors were bled. A total of 1,215 bottles were issued to hospitals and the remainder were utilised for plasma processing. No. 2 Advanced Base Transfusion Unit collected 2,520 pints during the year, of which 1,380 pints were forwarded by air to field transfusion units, the remaining 1,140 pints were issued to general hospitals. Never once during the twelve months did the advanced base transfusion unit refuse a request for whole blood from field transfusion units.

PROPAGANDA

A badge made of white metal, on which was superimposed a bronze star of India, was chosen by the Commander-in-Chief as a suitable

award to blood donors from amongst several designs submitted by the base unit. The units began to issue these badges in September.

PRODUCTION OF CRYSTALLOIDS

The production of crystalloids continued fairly steadily throughout the year. Between 1 January and 30 June 1944, No. 2 Base Transfusion Unit prepared 19,129 pints of approved crystalloidal solutions to which the advanced base transfusion unit added a further 2,665 pints. This figure was raised during the second half of the year to 32,107 pints by the base and 6,820 by the advanced base units. The combined output of the two units during 1944, thus amounted to 60,721 pints of approved solutions. In addition to isotonic saline and an isotonic glucose saline which contained 2·5 per cent. glucose and 0·42 per cent. sodium chloride, the base unit also prepared the following solutions :—

4·3 per cent. sodium sulphate (in pint bottles).
0·5 per cent. sulphanilamide in normal saline (in pint bottles).
3 per cent. sodium citrate (in pint bottles).
3 per cent. sodium citrate (in 4 oz. flats).
5 per cent. hypertonic saline (in pint bottles).
30 per cent. sulphamezathine sodium (in 4 oz. flats).
30 per cent. sulphamezathine sodium (in 5 and 10 cc. ampoules).

The indigenous output of blood transfusion bottles remained a constant source of worry until the end of May after which the output proved more than adequate for the remainder of the year. The handicap of having to work all the stills by kerosene stoves proved greater than ever. To provide the maximum output of distilled water that was possible under the circumstances, the stills were operated from 0430 hours to 1900 hours daily with the exception of Saturdays when they were stopped at 1230 hours to enable them to be cleaned out and overhauled. This was particularly necessary at Dehra Dun on account of the very chalky water, all attempts to procure a large water softener having proved unsuccessful. Six stills each producing approximately three and a half litres an hour were operated in June 1944. The number was raised to eight by October. The day was split into two shifts, one man being employed whole time during each shift.

Another major problem during 1944, relating to the production of crystalloids, was the procurement of A. R. sodium citrate and sodium chloride. To reduce the demands made upon the sodium chloride, a stock of Crookes glucose saline ampoules was put up in blood transfusion bottles. This conversion of ampoules into bottles might at first sight appear to provide the paradox of being both a waste and a saving of the unit's time. The ampoules could not be used with army transfusion apparatus, they were quite unsuitable for conveying across the Burma jungle, whilst the time taken to break open and empty a large number of them more than equalled that necessary for weighing out and dissolving the required amount of chemicals in several litres of distilled water.

The preparation of sodium sulphate, sulphanilamide saline and sulphamezathine sodium periodically imposed comparatively large demands upon the time of the small laboratory staff. There was, therefore, a reduction in the output of ordinary crystalloids during such periods. No complaint, direct or otherwise, was received by the unit in regard to any of them. No. 3 Base Transfusion Unit in Poona produced 36,256 pints of crystalloid solutions.

PRODUCTION OF PLASMA

The lack of 20 cm. pilot filters not only limited the amount of plasma that the units were able to prepare during the year, but this work, in consequence, also took up considerably more time than should have been necessary. Thus, at the beginning of 1944, No. 3 Base Transfusion Unit was fortunate in possessing a small stock of good 14 cm. Seitz pads, with which it was possible to filter 20 to 25 pints at each session. The total amount of plasma prepared by the base unit at Dehra Dun in 1944 was 2,857 bottles, of which 295 bottles were discarded, a figure which included any unsatisfactory bottles returned by units. Subsequently 314 bottles were refiltered providing a yield of 295, of which 150 were discarded, one entire batch being contaminated. The net output of good plasma for the year was, therefore, 2,393 bottles; this working out at an average of 3·8 donors bled for every pint of good plasma produced. A total of 4,997 pints of plasma was produced in Poona.

The following points were noted about wet plasma during the course of the year.

1. Plasma issued at a pH of 7·4 did not appear to be as stable as the more alkaline material. Such plasma was pale yellow or inclined to be green in colour and presented a slight fluorescent appearance in certain lights. It had been noted that this somewhat 'anaemic' material had not travelled well in England and the same impression was obtained on examining plasma after it had been sent on a long rail journey in India. In consequence, plasma was issued at a pH of 7·8 to 8 at which range it appeared to be more stable. A railway journey in India provided a good test of stability. Plasma found to be in good condition at the end of a thousand mile run almost invariably continued to keep well.

2. The lipoid-globulin complex continued to be a constant source of worry but not to anything like the extent in the plasma of pH 7·8 to 8 as it had previously done in the pH 7·4 stock. It may be added that this decided improvement preceded by several months, the policy of autoclaving the plasma containers which had then been adopted as a result of Bushby's hypothesis that the agent responsible for causing lipoid separation may be bacterial in origin.

3. A certain amount of the plasma that was passed through the extremely slow filtering pads developed large fibrin clots. Sometimes these pads would block up completely after quantities as small as fifteen pints had been passed through them. After the arrival of a pilot filter

in January 1945, this trouble had not occurred but as blood was collected into the acid hydrogen sodium citrate mixture, it was considered judicious to add 45 cc. of normal NaOH to each litre of plasma, the pH of which was reduced by the citric acid mixture.

4. All wet plasma, obtained from Bristol and returned from units, which was over two years old was found to be quite unsuitable for refiltering. Two years for such material would in fact appear to be its life in a tropical country.

ASSEMBLY OF APPARATUS

During the year, the base unit at Dehra Dun assembled a total of 23,445 sets and rewrapped or reconditioned 5,184 others. The bottle washing section, for which hot water was procured from the still overflows, had been designed so that seven men could deal efficiently with 2,000 bottles in eight hours, whilst a further five men could be employed on the initial cleaning of blood taking sets, etc. On an average approximately three men, however, were available during the greater part of the year. These personnel had to work extremely hard in order to maintain an adequate output. Only new tubing or material that had already received an initial rinse was taken into the rubber room. There tape was pulled through it, after which it was boiled for two hours in 1 per cent. solution of sodium hydroxide. Subsequently, it was connected first to a pressure-tap and then to a distilled water container before being hung up to dry.

STORE ORGANISATION

The store organisation remained precisely the same as that described for 1943; every genuine emergency demand was despatched the day it was received. Most of these demands were for sulphamezathine of which the following is an example of promptness of the organisation at that time. A telegram for urgent supply of 96 bottles of sulphamezathine by air was received by the base unit at Dehra Dun at 1915 hours. As it happened this amount had only been made by the laboratory the same afternoon and consequently it had to be capped and labelled before it could be packed. The consignment was ready to leave the unit by midnight. One of the four unit drivers, who had already completed a full day's work, left for Delhi shortly afterwards, a distance of 156 miles. The boxes were loaded into a plane at 0615 hours the next day in accordance with telephonic arrangements made with the RAF the previous evening. A telegram was despatched warning the advanced base unit to see that the consignment was transhipped from one plane to another at Calcutta without delay. At 1600 hours a telephone message was received at Dehra Dun notifying the unit that the boxes had already left Calcutta and should, therefore, reach their destination by 1800 hours, i.e. less than 23 hours after the receipt of the message at Dehra Dun during which time the bottles had been capped, packed and despatched over a distance of approximately 1,200 miles. Similar commitments were executed by No. 3 Base Transfusion Unit at Poona.

From August 1944, No. 3 Base Transfusion Unit was also called upon to store and distribute all stocks of penicillin which arrived in India for the India Command and ALFSEA. As much as 687,000 mega units were stored in this unit at one time requiring seven cold chambers (114,000 cubic feet) for its storage. In the course of two or three months this additional work exceeded that of supplying transfusion fluids. The unit continued to store and distribute penicillin till April 1945.

TRAINING

A six-weeks course in transfusion duties for prospective unit field transfusion officers was attended by medical officers who were attached to No. 2 Base Transfusion Unit. It included the five-day resuscitation course which presented the theoretical aspect of the subject: a fortnight in the assembly rooms where the officer was required to spend a certain amount of time in every section including the washing of transfusion bottles, the operation of autoclaves and the maintenance of indigenous Primus stoves ; a week in the laboratory and another week in stores. Lectures on the maintenance of refrigerators, frequent attendance on bleeding teams, the administration of transfusions in the local IMH and the reading of current literature on transfusion and resuscitation, copies of which were made available by the unit, completed the training. Seven courses for officers were also held at Poona and were attended by a total of 88 officers.

In May, the base unit managed to procure the services of 13 BORs (RAMC) who were attached to it for training. Their number was subsequently raised to 17.

The men were made to work in as many departments as possible but the acute shortage of personnel made it impossible to move them around to the extent that ideal training demanded. In addition, lectures were given twice a week over a period of three months to the men and the members of the WAC(I). The lectures were delivered by officers between 1700 and 1800 hours, each lecture being given on two successive days to enable half the unit to attend one day and half on the following day, thus reducing interference with unit work to a minimum. It had been the intention to examine men who had attended such courses as these BORs were subsequently to be posted to the unit as transfusion orderlies when the new war establishment was sanctioned. Instructions were, however, received from the War Office that only those orderlies who had been trained in the United Kingdom should be so graded.

FIELD TRANSFUSION UNITS

Demands of the Field Forces : During this time the demands of the field force were steadily increasing. The responsibility for supplying the Eastern Army (later the Fourteenth Army) had been given mainly to No. 2 Base Transfusion Unit.

Units Available : The formation of the Indian advanced base transfusion units in Calcutta and Bangalore released No. 5 and No. 28

Field Transfusion Units for use with the field forces early in 1944. No. 27 Field Transfusion Unit was also made available.

Operations : Early in 1944, the Japanese struck in the Arakan and invested a division in a 'box'. During this phase No. 28 Field Transfusion Unit was overrun and one orderly and the driver were killed, while several others in the unit were wounded. The unit was withdrawn and reformed as soon as the 'box' was relieved.

Assam : No. 2 Field Transfusion Unit remained at Imphal. This unit collected supplies sent from Calcutta by air and distributed them to medical units in the lines of communication area and the IV Indian Corps. Blood was flown from No. 2 Advanced Base Transfusion Unit in Calcutta and was collected from the airstrip and distributed by No. 2 Field Transfusion Unit. The unit was attached to a CCS. A 'dump' or reserve stock of transfusion fluids was held and a subsidiary reserve stock was maintained in the Imphal depot of medical stores for dispersal reasons.

The following instructions for the distribution of transfusion fluids to the IV Indian Corps were issued :—

Maintenance of Transfusion Fluids—IV Indian Corps

(i) *Field Ambulances :*

(a) Field ambulances in operational areas were to hold a minimum of three infusion supply boxes.

(b) As soon as one box was empty, it was to be returned by ambulance to the most forward CCS, where it was exchanged for a fresh box held in that unit's medical stores.

(c) Field ambulances situated behind the most forward CCS exchanged their boxes with the nearest field transfusion unit (i.e., No. 2 Field Transfusion Unit). They did not maintain their supplies from a more forward reserve dump except in very special circumstances.

(d) Field ambulances wishing to replace individual bottles during quiet periods were under no circumstances to obtain these from CCSs holding reserve supplies but, if considered necessary, the replacement was to be arranged with the nearest field transfusion unit irrespective of their position in the field.

(e) Any field ambulance withdrawn from the IV Indian Corps area was to surrender to the nearest transfusion unit all infusion supply boxes with the exception of one as stipulated on the war equipment tables which was kept to cover any small emergency.

(ii) *CCS :*

(a) All CCSs held a minimum of three infusion supply boxes packed in the standard way together with two 14 partitioned boxes (P.V. 27111), which hold glucose saline and saline.

(b) Boxes containing empty bottles and used plasma sets were returned to the nearest field transfusion unit which issued new boxes in lieu. Individual bottles were not forwarded except in special circumstances.

(c) The most forward CCS, in addition to its own stock, held a further ten infusion supply boxes and four 14 partitioned boxes in its medical stores. These boxes were for issue to field ambulances and mobile surgical units working ahead of the CCS. The packing of these boxes was not altered by the CCS. This stock when reduced by a half was to be replenished from the nearest transfusion unit to which all empty bottles and boxes were returned.

(d) In the event of no member of the army transfusion units being attached to the most forward CCS, the resuscitation officer to the latter unit was held responsible for the maintenance of this divisional reserve, and for ensuring that stocks were not frittered away in an uneconomical manner.

(e) When the forward CCS is side-stepped by another such unit it handed over its divisional transfusion reserve stocks to the latter immediately it was opened to receive casualties.

Arakan : In Arakan, No. 8 Field Transfusion Unit was responsible for the maintenance of transfusion supplies. It was located at CCS level, where it was able to assist with resuscitation in a group of three such units. This field transfusion unit and a sub-depot medical stores, located half a mile away from it, held considerable stocks of transfusion equipment. As in Assam, units obtained their supplies from the field transfusion unit but had been warned to proceed to the sub-depot medical stores, should hostile action render the field transfusion unit inoperative. Whenever extra casualties were anticipated, the field transfusion unit proceeded forward to work with a MDS. On such occasions, one man was left behind to supervise the maintenance of the transfusion stock. To ensure effective maintenance of the latter an intermediate dump was established at a base depot medical stores at Chittagong where the field transfusion units were able to proceed directly by road when occasion demanded. This reserve was split into two blocks : (a) to protect from an air raid and (b) to ensure that supplies intended for forward units were never reduced by those in the rear. The maintenance of the one was the responsibility of the field transfusion units for whom it was specifically reserved, and of the other that of the stores which issued it to line of communication units.

No. 28 Field Transfusion Unit with a mobile surgical unit was attached to MDS operating to the east of the Mayu Range in Arakan. In addition to its resuscitation duties, it was held responsible for ensuring that the field ambulances were maintained with adequate supplies ; replacements being obtained from the corps' dump held by No. 8 Field Transfusion Unit.

The first real test of this organisation came at the beginning of February 1944, when the 7th Indian Division successfully thwarted the Japanese thrust in Arakan. Almost at the beginning of this attack, No. 28 Field Transfusion Unit was rendered ineffective, the driver and one orderly having been killed, another orderly seriously wounded whilst the officer suffered an injury to his right arm. The 7th Indian Division 'Box' possessed adequate stocks of transfusion fluids and eqiupment

in spite of the fact that two-thirds of the plasma supplied had fallen amongst the Japanese. A visit by officer commanding, No. 2 Base Transfusion Unit to this part of the front at the end of February 1944, disclosed that all units were well satisfied with the supply system, whilst the DDMS of the corps described it as the best of its kind. The Japanese attack had, however, disclosed that there was far too much laxity permitted regarding the issue of transfusion fluids for air dropping. The store at Comilla received two large demands for parachute supplies in the course of thirty-six hours which bore no relation to the casualties suffered, and reduced the stock held there to nothing.

To provide for future eventualities the following organisation was set up.

Parachute Supplies:

(i) Three standard paratroop boxes were introduced, one of which contained wet plasma, a second plasma and sulphanilamide saline and a third crystalloids ; all three were complete with giving sets and carried distinguishing letters painted on the outside of their lids.

(ii) The store responsible for parachute supplies was instructed not to issue more than four boxes of each particular pack to any one medical unit at a time, the advanced base transfusion unit was to be phoned in the event of extenuating circumstances.

(iii) Initially the stock was fixed at 60 paratroop boxes comprising 180 bottles of plasma, 120 bottles of crystalloids and 60 bottles of sulphanilamide saline, a quantity that was subsequently increased. The store was maintained by rail from Chittagong and by air from Calcutta in emergency.

Through these means the Long Range Penetration Groups, the 81st West African Division and any unit for whom air dropping became essential, were supplied.

The paratroop boxes which weighed, when packed, 26 lbs. each, fitted into every type of container, and proved very successful. Very few bottles were found broken in these boxes.

Reinforcements in the Fourteenth Army: No. 27 Field Transfusion Unit arrived in the Arakan in February 1944, with the 36th British Division, and remained there until shortly before the monsoon. During this period, though it was attached to a MDS, this unit did less resuscitation work than it could, owing to the fact that the division considered it so much a part of the formation that it did not permit the field transfusion unit to be posted away from the divisional area.

No. 32 Field Transfusion Unit (in reserve) was utilised in training and providing personnel for No. 28 Field Transfusion Unit and advanced base transfusion unit. This unit was reformed at the base in July 1944.

No. 5 Field Transfusion Unit, which had been in Bangalore, was re-equipped by No. 2 Advanced Base Transfusion Unit at the beginning of April 1944, and proceeded to Manipur Road, where it did excellent

resuscitation work. It was responsible for the 2nd British Division during the battle of Kohima. Subsequently this unit proceeded to Imphal where it took over the forward distribution duties which had been carried out by No. 2 Field Transfusion Unit during the preceding twenty months.

No. 28 Field Transfusion Unit together with a mobile surgical unit was attached to a MDS. Before the Japanese attack in February 1944, this unit had collected blood as and when required. Donors had responded well. The unit was using approximately 10 to 15 pints of blood per week. One of the most successful cases treated by it was a man who had sustained 13 shrapnel holes in his intestines. He was transfused approximately ten hours after receiving his injuries when his systolic blood pressure was 50 mm. Hg. He was given three pints of blood and five pints of plasma. He was subsequently placed on a stomach suction drip and was given crystalloids for a further four days. One pint of blood was given on the second day.

No. 8 Field Transfusion Unit, during the period January to May 1944, was attached for short periods to a MDS with one and occasionally two mobile surgical units. The greater part of the time, however, was spent at CCS level, where it supervised the resuscitation work in three CCSs which were sited together. Blood collected from neighbouring units, was stored in the unit refrigerator and issued as required to the CCSs. In about five months the unit transfused 52 patients. The total amounts of transfusion fluids given to 51 of these cases were as follows :—

Whole blood	81 pints.
Plasma	91 pints.
Crystalloids	110 pints.

One fatal case of burns, which received 43 pints of plasma, has been omitted from the above figures.

Assam—Imphal Siege : Between 17 March and 24 June 1944, No. 2 Field Transfusion Unit was the only transfusion unit operating in the Imphal plain where it acted principally as a distribution unit. The following figures show the work carried out during the siege :—

Total number of casualties admitted to medical units	8,044	
Total number of casualties who died after admission ...	464	
Total amount of plasma used	2,289	bottles
Total amount of whole blood flown into Imphal from the advanced base	498	bottles
Total amount of isotonic glucose saline used ...	2,217	bottles
Total amount of isotonic sodium chloride used ...	818	bottles
Total number of giving sets utilised	1,095	sets
Estimated number of casualties treated with plasma ...	843	
Average number of bottles of plasma used per case ...	3	bottles
Percentage of casualties resuscitated with plasma ...	10·4	per cent.
Percentage of casualties who died after admission ...	5·7	per cent.
Estimated number of cases who recovered after resuscitation	379	
Percentage of cases who recovered after resuscitation	4·7	per cent.

During the battle of Kohima, No. 5 Field Transfusion Unit was attached to a general hospital near a CCS at Manipur Road, approximately three hours journey from Kohima itself. This unit was responsible for resuscitation in both units to whom cases were generally admitted on alternate days. No details of the resuscitation work carried out by this unit are available. Blood was collected from local units some of which was sent forward to the MDS. The unit worked extremely hard for several weeks. Subsequently, this unit proceeded to Imphal where it took over the forward distribution duties, which had been carried out by No. 2 Field Transfusion Unit during the preceding twenty months.

TRANSFUSION SERVICE—1945

Operational commitments in Burma having increased it became necessary to intensify the output of base transfusion units. This made it necessary to increase the staff and accommodation of these units.

FIELD TRANSFUSION UNITS

There were only four field transfusion units available for the Fourteenth Army and the whole of its lines of communication during 1945. The force consisted of the 7th, 19th, 20th and 17th Indian Divisions, 2nd Tank Brigade and the 2nd and 36th British Divisions, with an Indian and East African division in reserve. The transfusion units operated as follows.

No. 5 Field Transfusion Unit : This unit was attached to a BGH at Imphal during January and February 1945. It acted as a headquarter's distribution unit for most of the time but did no active resuscitation work and only collected a limited quantity of blood. In March 1945, it was able to move forward to operate with a CCS under the IV Indian Corps.

Nos. 2 and 27 Field Transfusion Units : These units operated with the XXXIII Indian Corps. Occasionally, they were employed at MDS level alongside a mobile surgical unit, but, as a rule, they were sited at forward medical centres which generally consisted of one or two CCSs and a MFTU. The centres were always located near improvised air strips, on which Dakotas were able to land, and by which all transfusion supplies were forwarded from Chittagong. Transfusion fluids were sent by the transfusion units to the mobile surgical units operating at MDS level by light aircraft. No. 2 Field Transfusion Unit collected approximately 90 pints of blood in the field and resuscitated approximately 200 casualties. No. 27 Field Transfusion Unit collected approximately 150 pints in the field during a period of three months, but the exact number of persons transfused is not known.

No. 32 Field Transfusion Unit: This unit operated with the IV Indian Corps and was principally employed at CCS level where, in addition to resuscitation work, it maintained, by means of light aircraft, the mobile surgical units which were operating ahead of it. Details of the

precise amount of blood collected in the field and of the number of cases transfused are not available, but there is no doubt that the unit rendered valuable service to the troops in the area.

Nos. 38, 39, and 40 Field Transfusion Units : These units arrived in India in February 1945 and proceeded direct to Imphal. They remained there with nothing to do until April 1945.

No. 36 East African Mobile Transfusion Unit : The officer commanding was posted to another unit by the East African headquarters immediately the unit arrived in South East Asia. It played no active part in the operations.

Difficulties : The absence of No. 1 Advanced Base Transfusion Unit at Imphal was very keenly felt. Its presence there would have released a badly needed field transfusion unit for other duties. A considerable quantity of blood could have been collected from the many troops in the area. From the organisation aspect, it would have been invaluable, as it would have been able to maintain a close liaison with the field transfusion units and with the Headquarters Fourteenth Army. It could have been effectively maintained by rail and road from Dehra Dun and would have relieved very considerably the over-worked advanced base transfusion unit at Calcutta.

Distribution sections were badly required at Chittagong, and certain of the advanced medical centres. The need for distribution sections had been pointed out in the report submitted by the officer commanding No. 2 Base Transfusion Unit after his first tour of the forward areas in early 1943. It was disappointing that these could not be established after an amended war establishment for a base transfusion unit had made provision for them. Their absence not only seriously impaired the efficiency of the service, but reduced very considerably the clinical work which the field transfusion units were able to perform, for much of their time was unavoidably taken up with the collection and distribution of blood on the various airstrips.

The shortage of field transfusion units provided an obstacle which, though very well recognised, could not be surmounted at the time owing to the acute shortage of manpower and mobile refrigerators. A field transfusion unit could not accompany the 36th British Division, as a three-ton truck could not travel with the force, and none of the jeep trailer refrigerating plants were available at that time. It was not possible to provide its mobile surgical units with whole blood as they had no means of storing it. The time taken to fly blood to the appropriate site after receipt of a signal was such that the blood was not likely to arrive at its destination in time. This method might have been attempted had there been an advanced base transfusion unit at Imphal.

Some of the petrol engines belonging to the field transfusion unit refrigerators were worn out and No. 2 Base Transfusion Unit, which had received no spare engineering equipment of any sort since August 1944, had exhausted its stock. A mechanic constantly travelled from one unit to another during this period to provide some form of refrigeration. Small mobile ice making plants formed another item of

engineering equipment which would have been invaluable at certain periods.

The field transfusion unit officers were sometimes obliged to wait rather longer than they considered justifiable for their stores owing to the fact that signals were sometimes very slow in reaching No. 2 Advanced Base Transfusion Unit and were occasionally so garbled that a repeat became necessary. Misunderstandings arose, one of which gave rise to the belief that the transfusion service would not be able to provide more blood should larger stock be required. Such views could easily have been eradicated had it been possible for a senior transfusion officer to visit the forward areas. It may be recorded, however, that the all-round output of the base and advanced base units could not have been increased without more staff.

When Chittagong became the air-supply centre for Burma and the Arakan, certain difficulties arose. The three supply routes from Calcutta to this port became very congested. The sea route became most unreliable, goods traffic took anything upto three weeks to reach its destination, whilst only a strictly limited quantity of stores could be sent either by air or by the passenger train cum river steamer service.

Blood arriving at Chittagong had frequently to be taken out of the Calcutta plane for despatch forward, not only in another plane, but sometimes from another aerodrome. As the two airports were several miles apart, delay was inevitable and blood sometimes remained at an airport for nearly 24 hours.

THE COLLECTION AND ISSUE OF TRANSFUSION FLUIDS INCLUDING WHOLE BLOOD

Requirements of citrated blood and plasma for forward areas were estimated at 5,000 donors per month from Poona and 3,000 from Dehra Dun. Accordingly a big donor drive was instituted. The response did not come up to the target figure but, nevertheless, was exceptionally good. The best effort was 3,881 donors at Poona in July 1945. To obtain these numbers it was necessary to send detachments to neighbouring stations, e.g., Bombay, Deolali, Nasik, Ahmadnagar.

The best daily effort by an individual medical officer was the bleeding of 462 donors by a detachment from No. 3 Base Transfusion Unit under the officer commanding No. 1 Indian Base Transfusion Unit.

A big detachment was scheduled to function in Secunderabad and Kamareddi in September 1945, so that adequate blood and plasma cover could be given to the forces for the invasion of the Japanese occupied South East Asia, but the cessation of hostilities resulted in the cancellation of this plan.

PRODUCTION OF CRYSTALLOIDS AND WET PLASMA

The quantity of wet plasma and crystalloids prepared by No. 2 Base Transfusion Unit during the period January-March 1945, was

almost double of that for any previous quarter, amounting to 30,767 pints of approved crystalloids and 1,039 pints of wet plasma. To this total No. 2 Advanced Base Transfusion Unit contributed a further 1,369 pints of crystalloids. As in the past, No. 3 Base Transfusion Unit at Poona continued to concentrate on the production of wet plasma, all of which it held in reserve for ALFSEA. This plasma was called forward by No. 2 Base Transfusion Unit, as and when required.

On cessation of the war the transfusion units were disbanded and a centralised transfusion unit, called the Army Transfusion Centre, was established at Poona, to cater for the transfusion needs of the Army in India.

APPENDIX A

The Civil Blood Transfusion Services in India

The outbreak of World War II found India lacking in an effective peace time organisation on which could be built up a blood transfusion service, capable of meeting the demands of modern war, and able to undertake the large scale preparation of blood and blood products, and their supply for the armed forces and civil defence services.

In some of the larger towns, sporadic attempts had been made, usually by voluntary organisations, to establish small panels of blood donors for the local hospitals. It was only in a few of the large cities, such as Bombay, Madras and especially Calcutta, that any serious attempt had been made before the war to establish organised blood banks.

The outbreak of war in September 1939, involving as it did the Indian Army, suggested the advisability of organising some form of transfusion service in India, so that blood and its derivatives, serum and plasma, might be made available for the armed forces, at home and overseas. This gave impetus to the work of the existing blood banks especially in experimental directions. One new blood bank was established at Lahore in October 1940, where experiments were conducted with a view to preparing blood serum in a form suitable for transport overseas. It was not anticipated at that time that the work had more than a limited application or that blood transfusion would shortly become a matter of nation wide interest.

Soon after Japanese occupation of Burma, it was obvious that blood for the transfusion of the wounded would not only be needed for the armed forces, but also for the civilian population, especially in Assam and Bengal.

In January 1942, the then DGIMS, addressed all provincial administrative medical officers pointing out the vital importance of instituting a blood transfusion service as part of their civil defence organisation and indicating the lines this should follow. In February 1942, Government of India deputed a special officer (Dr. S. R. Pandit) to visit all the provinces to advise on the best means of implementing the proposals for establishing a blood transfusion service.

From time to time conferences were held at the centre, attended by blood bank workers from all parts of India, including representatives of the military medical authorities and experts from the army transfusion service, when this service began operating in India. At these conferences, the experiences gained by workers in this field, both in India and abroad, were fully discussed. By the end of 1942, a definite policy for the organisation of provincial blood transfusion services, both for peace and war, had been formulated and approved by the Government of India. In consultation with the army experts the criteria to be observed by all blood banks in the preparation of blood and its products, were also drawn up.

An abridged version of an official report compiled from the files of the DGIMS by Lieut.-Colonel L.A.P. Anderson.

BLOOD TRANSFUSION OFFICER ON SPECIAL DUTY AT THE CENTRE

In the meantime Government of India had appointed in October 1942, a special officer (Lieut.-Colonel L. A. P. Anderson) at the centre whose duties were to co-ordinate the activities of all the civil transfusion services. Through this officer all the blood bank workers were kept informed of any advances in knowledge and experience in this field. He maintained close liaison with the Indian Red Cross and other similar organisations and the army transfusion service. Tours of inspection formed a large and essential part of his duties to keep himself in personal touch with the various provincial blood banks. The DGIMS had recommended to the Government that an officer on special duty for blood transfusion should continue to be posted at the centre to co-ordinate and guide the provincial blood transfusion service until such time as this service was reasonably well established on a peace time basis.

BLOOD TRANSFUSION OFFICERS IN PROVINCES, STATES AND STATE AGENCIES

Whilst the necessity for the establishment of an effective blood transfusion service in India had been brought to the fore by urgent war needs, it was recognised by the Government that such a service would also be required after the war and should form a part of normal peace time medical facilities. Government of India accordingly approved a scheme for the organisation of blood transfusion services on a provincial basis, which had been drawn up by a committee of experts at a meeting held in New Delhi in December 1942, under the chairmanship of the DGIMS.

The scheme covered all the requirements of civilian transfusion service both for peace and war. It dealt with the appointment of blood transfusion officers, training of medical officers and personnel, the supply of equipment and materials to hospitals, the formation of transfusion units, the enrolment of donor panels and the establishment, where necessary facilities were available, for the manufacture of serum or plasma.

The key post in the transfusion service was that of blood transfusion officer. This officer was the executive head of the transfusion service in each province and was responsible for the training of the other medical personnel and the organisation of the service generally.

There was considerable delay in the appointment and training of blood transfusion officers. This delay was to a great extent responsible for the slow progress made in organising an adequate transfusion service. By the end of 1943, every province, except Bombay (who did not propose to fill the appointment) and Bengal, Punjab, Assam and Sind (who were still considering the appointment), as well as a large number of Indian States and States' Agencies, had selected their blood transfusion officers, either for part time or whole time work. The provincial blood transfusion officer had to train other medical officers to take charge of the transfusion work in individual hospitals.

In many centres, regular courses of instruction were held by the both military and civil blood transfusion officers at provincial

headquarters. In these centres, many medical officers received special training in resuscitation and practical blood transfusion. The provinces of Madras, Bihar, Bombay and Bengal had been most active in this matter. In addition, where circumstances precluded the holding of regular courses of instruction at provincial headquarters, practical training by means of a few lectures and demonstrations had been given to medical men by the blood transfusion officers during their tours in the districts. In this way 257 Government medical officers and 304 non-official medical practitioners had received a modified training ; four provinces followed this practice.

All the provinces had made a start at providing facilities for resuscitation of patients including blood transfusion in their hospitals. Although these arrangements were very incomplete, nevertheless, some progress had been made especially during 1944 and 1945. The organisation, however, was mainly established in the provincial headquarters hospitals and was still deficient in hospitals in the districts.

Most of the provinces reported that they had organised a number of blood transfusion units consisting of a medical officer trained in resuscitation and certain subordinate personnel. Such units had been provided at nineteen headquarters hospitals in these provinces. Madras, Bihar, the United Provinces and the Central Provinces reported that transfusion units had been established at 26 of their district hospitals. Only Madras and Orissa appeared to have appointed trained subordinate personnel for their transfusion units. The remaining provinces had gone no further than providing one trained medical officer at certain hospitals. In a few cases special wards or beds had been earmarked for the resuscitation units.

STORES AND EQUIPMENT

As regards the provision of equipment for transfusion work, all the provinces reported that certain of their larger hospitals had been equipped. The provision of transfusion equipment for the hospitals had been greatly hampered by the difficulty in securing sufficient number of essential apparatus, such as blood taking and giving sets, blood bottles, etc.

BLOOD TRANSFUSION SERVICES IN PROVINCES

The total amount of serum or plasma in stock in all the civil blood banks (excluding Calcutta) in December 1943, was in the neighbourhood of 2,000 pints just enough for about 700 transfusions. Only seven of these banks had a reserve of more than 180 pints. Excluding Calcutta the maximum quantity of serum or plasma in stock at any bank at the end of November 1943, was 450 pints. Up to the end of 1943, there were 16 civil blood banks and processing centres throughout India, 12 in the provinces and four in centrally administered areas or Indian States. All of these, except the Calcutta Blood Bank, were controlled by the local administration ; the latter being controlled by the centre.

They had enrolled panels of donors and established bleeding clinics. In most centres the blood was processed into serum or plasma.

It was estimated that blood transfusion was required for 10 per cent. of the wounded in a battle or an air raid, and that an average of three pints was required for each case. Experience of air raids in different parts of the world had shown that the wounded, that is those not killed outright, will comprise about 3/5th of the total casualties. On this basis, therefore, 450 pints of serum was considered sufficient for 1,500 wounded or 2,500 total casualties.

The average collection of blood per month during 1943, by all the blood banks together, excluding Calcutta, was under 500 pints. The average monthly collections in each of these banks varied from two pints to 90 pints. Only five of them collected more than 50 pints a month.

Ninety pints of blood, the maximum collected monthly by any of these banks, represented perhaps 30 to 40 pints of serum or plasma, the only form in which blood could be preserved for storage. In actual practice, however, much of the blood collected in the banks was issued to neighbouring hospitals immediately for whole blood transfusions leaving only a small balance for further processing. It was obvious, therefore, that the building up of an adequate reserve of blood products for stocking against possible air raids or for distribution to hospitals in the mofussil was a very slow process, even in the more active banks.

At the end of 1943, pending the more wide-spread use of blood transfusion services in the provinces or until the civil blood banks were utilised for the supply of serum to the army on a large scale, restricted production for their immediate needs was perhaps desirable in those areas classified as 'white' under the civil defence organisation to avoid unnecessary waste of blood, but unfortunately these conditions obtained in most of the banks in the 'red' areas also.[1] It cannot be doubted that a series of air attacks in any of these areas, other than Calcutta and possibly East Bengal generally, would have found their stock of blood products entirely inadequate for even a fraction of the casualties.

The work done by all the provincial banks and the Calcutta Blood Bank from 1 January 1944 to 30 June 1945 is given in Table I.

TABLE I

Work done by Provincial blood banks and Calcutta Blood Bank during 1 January 1944 to 30 June 1945.

Banks	No. of donors	Blood collected (pints)	Whole blood issued (pints)	Serum plasma prepared (pints)	Serum plasma issued (pints)
Provincial Blood Banks ...	41,430	17,689	1,090	10,724	11,136
Calcutta Blood Bank ...	26,417	11,032	800	7,580	8,331

[1] See also volume on 'Administration', Chapter XIX, page 417.

Whole blood banks were maintained at fourteen hospitals in nine provincial headquarters and five district hospitals in Bihar only. Regular donor panels were maintained at twelve headquarters hospitals by ten provinces and at 22 district hospitals by six provinces.

Stocks of serum or plasma were maintained at 27 headquarters hospitals in 11 provinces and at 46 district hospitals in six provinces. Ten provinces maintained mobile transfusion units.

Perhaps the best indication that the blood transfusion services were slowly taking shape, can be obtained from the following recorded figures of actual blood (including serum and plasma) transfusions which had been given under the auspices of the provincial transfusion services in Government controlled hospitals. These figures do not include transfusions given in any institution in Assam and non-Government institutions in the Indian provinces. The figures are far from complete and should be regarded as of no significance other than just indicating the general trend of events.

At headquarters hospitals, 1942/43	1,246
At headquarters hospitals, 1944/June 1945	3,476
At district hospitals, 1942/43	197
At district hospitals, 1944/June 1945	941

THE CALCUTTA BLOOD BANK

The Calcutta Blood Bank was established in January 1942, by the Government of India with collaboration of the Indian Research Fund Association and the Bengal branch of the Indian Red Cross Society, with its headquarters at the All India Institute of Hygiene and Public Health. It was the only blood bank of any real size in India at the time. It consisted essentially of a central blood bank and clinic, together with a processing centre for the manufacture of both liquid and dried serum, located at the institute and subsidiary bleeding centres in and outside Calcutta. It maintained travelling units which visited tea gardens, coalfields and other industrial organisations throughout the province for the purpose of collecting blood.

The bank was under the general supervision of the Director of the All India Institute of Hygiene and Public Health (Dr. J. B. Grant) to whose drive and organising ability the success of this bank was to a large extent due. He had associated with him an expert staff of medical men, bacteriologists, chemists, pharmacologists, nurses, technicians and propagandists. The majority of the technical experts carried out the blood bank work in addition to their own duties in the institute. The work of the office of the bank and the duties of receptionists and the propaganda and publicity work were carried out by a body of voluntary workers, whose enthusiasm and energy enabled the bank to maintain a constant supply of voluntary donors.

After this bank went into production in February 1942, it secured 64,842 voluntary blood donors, of whom 61,542 were bled; many of them offering themselves at regular intervals for repeated donations. These donors provided a total of 31,000 pints of blood. From this 9,119 bottles (each one pint) of liquid serum and 3,034 bottles

(each 400 cc.) of dried serum were manufactured. The average monthly collection of blood (11 months) amounted to 1,592 pints and the bank issued on the average over 220 pints of serum (including 50 pints of the dried product) and 32 pints of whole blood each month to the army and various hospitals. In addition, the institute carried out important investigations into various problems connected with the production of serum, notably in relation to the manufacture of the dried product and to the determination of a standardised technique in the processing of blood.

The Director of the All India Institute of Hygiene intimated that his other commitments were such that he could not give sufficient time to the supervision of the blood bank organisation, and asked to be relieved of these responsibilities with the exception of the processing laboratory. The Bengal Government, which had hitherto not appointed a blood transfusion officer, was, therefore, requested to fill this appointment. The officer appointed by the Bengal Government was to take over the organisation of the blood transfusion service in Bengal, including the Calcutta Blood Bank, less the processing laboratory. The Government of Bengal accepted the Government of India's request and in November 1944, sanctioned the appointment of a blood transfusion officer. After prolonged negotiations it was agreed that with effect from March 1945, the Bengal Government would assume responsibility for the blood bank clinic, office, donor organisation and also the processing of serum, less the desiccating plant which would remain at the All India Institute of Hygiene under the control of Government of India. The equipment and fittings of the Calcutta Blood Bank were taken over by Bengal Government at an agreed valuation and arrangements were made to install the bank in the Medical College Hospital, Calcutta.

The work of the blood bank and processing laboratory continued very actively until September 1944. From September 1944 to 30 June 1945, the average number of donors bled monthly fell to 549 against a monthly average of 2,714 for the previous ten months. At the same time the production of serum declined from a monthly average of 705 pints to 250 pints.

PRODUCTION OF DRIED SERUM AND PLASMA

Blood serum and plasma in the dried state keeps indefinitely and offers no special problems of storage or transport. It is readily reconstituted in the liquid form for transfusion purposes by the simple addition of distilled water. It was, therefore, considered an ideal product for a country where transport and cold storage facilities were deficient, and especially for use in forward operational areas.

Early in 1941, a pilot desiccating plant had been installed at the All India Institute of Hygiene, Calcutta, and experiments carried out there during that year showed that the manufacture of dried serum by the accepted technique of drying from the frozen state was practicable in India. Accordingly two desiccating plants of the 'Desivac' type were ordered from the USA by the Government of India.

One of these plants was installed at the All India Institute of Hygiene, Calcutta in December 1942, and by December 1943, it was in full production. This plant produced approximately 90 bottles of dried serum per week, each bottle containing the equivalent of 400 cc. of reconstituted serum. Certain additional equipment for this plant was also ordered from America.

The second 'desivac' plant, on arrival, was installed at the Haffkine Institute, Bombay, for the manufacture of dried plasma. Owing to delay in the shipment from the USA of certain air-conditioning equipment which was essential for this work, the production at Haffkine Institute plant was delayed for several months. Its capacity was approximately the same as that of Calcutta plant. Meanwhile, in the Haffkine Institute also, dried plasma was being produced on a small scale by a locally manufactured plant operating on the same principle as Calcutta's pilot plant. The output of dried serum and plasma, both from Calcutta and Bombay was mainly earmarked for the army and civil defence services.

Both Calcutta and Bombay carried on production of dried serum and plasma satisfactorily. The quantities prepared, expressed as reconstituted normal serum or plasma, during the eighteen months (January 1944 to June 1945) were as follows :—

Institute	Dried serum	Plasma
All India Institute of Hygiene, Calcutta	2,687 pints	166 pints
Haffkine Institute, Bombay ...	146 pints	273 pints

The Calcutta figure for 1945 represents two months working only. Owing to a breakdown in the supply of 'dry ice' required for freezing the serum prior to drying, the 'desivac' plant was out of operation during the rest of the period.

THE TRANSFUSION SERVICES OF THE INDIAN RED CROSS SOCIETY

In some of the larger cities, such as Calcutta and Bombay, the Indian Red Cross Society was operating blood banks and supplying donors and blood to the local hospitals long before there was any idea of an official blood transfusion service. The society's help and co-operation in the organisation and subsequent development of the provincial blood banks and transfusion services had been of the greatest value.

Amongst voluntary organisations may be mentioned the Civil Hospitals Emergency Committee, Bombay. This body came into being in February 1944, and among other activities operated a blood transfusion service exclusively for the civil hospitals of the city, at a time when there was no Government transfusion service.

During the period February 1944 to June 1945, this organisation secured 917 voluntary donors and collected 323 pints of blood, which was supplied to the various hospitals either as whole blood or as plasma.

During the same period, the Bombay branch of the Indian Red Cross Society secured 1,727 voluntary and 1,378 paid donors and collected 1,061 pints of blood. This blood was sent to the Haffkine Institute, Bombay, for the manufacture of plasma and was not supplied direct to the hospitals.

In Calcutta between January 1942 and March 1945, before the provincial transfusion service came into being, the civil transfusion service working under the Bengal branch of the Indian Red Cross Society supplied local hospitals and private practitioners with 845 pints of whole blood and 155 pints of serum.

APPENDIX B

Transfusion Packs

1. *Box—Infusion Supply Paratroop.*

Marked 'W P' Weight 26 lbs.

Contents :	Plasma wet	bottles	6
	Set—plasma giving	No.	3

2. *Box—Infusion Supply Paratroop.*

Marked 'G S' Weight 26 lbs.

Contents :	Glucose saline, isotonic	bottles	4
	Saline, isotonic	bottles	2
	Set—saline giving special	No.	2

3. *Box—Infusion Supply Stanpack.*

Weight 78 lbs.

Contents :	Plasma or serum, dried	bottles	8
	Glucose saline, special for reconstitution of plasma ...	bottles	8
	Glucose saline, isotonic	bottles	4
	Saline, isotonic	bottles	2
	Set—plasma giving	No.	4

4. *Box*—14 *Partition—Stanpack.*

Weight 56 lbs.

Contents :	Glucose saline	bottles	10
	Saline, isotonic	bottles	4

CHAPTER XXX

Chemical Warfare

From the beginning of World War II defensive measures against chemical warfare were instituted. An organisation was gradually developed both for offensive weapons and defensive equipment. The DMS in India was responsible for medical aspects of chemical warfare, supply and specification of food testing sets, training of medical officers in medical aspects of chemical warfare, provision of touring teams for lectures in army/command areas and for co-ordination of instructions given by part time medical advisers in formations. The physiological adviser on the staff of Directorate of Weapons and Equipment was also adviser to the DMS on chemical warfare matters. The chemical warfare sub-committee under the chairmanship of Deputy Chief of General Staff considered from time to time all aspects of chemical warfare and made recommendations to the Chiefs of Staff Committee. Membership of this committee was at director level and according to matters under consideration, directors concerned were invited to attend the meetings. The committee controlled the priorities of work at Chemical Defence Research Establishment (India) [(CDRE(I)], and considered such technical problems as were referred to it. A representative of the DMS was a member of this committee.[1]

INSTRUCTIONS

In addition to actual training and issue of a manual on chemical warfare, the Medical Directorate issued a small pamphlet on the disposal and treatment of gas casualties on the scale of one per medical officer and assistant surgeon.

DEFENSIVE EQUIPMENT

Supply and production position never enabled the scale of defensive equipment authorised to be implemented fully in all items. During 1939-1942 supply of respirators barely sufficed to enable formations and drafts proceeding overseas to be equipped with respirators and unit antigas equipment, e.g., oil skin clothing, etc., was in general not available in India for issue before departure. In most cases a reduced scale of other essential items or personnel equipment, i.e., one tin of ointment and one packet of eye shields, were issued. Since priority was given to formations proceeding overseas there were grave shortages of equipment in India for training. On the entry of Japan into the war there was serious deficiency in all essential items including respirators in all units in India. Urgent demands were placed on the United Kingdom and indigenous production of general service (GS) respirators was stepped up from 20,000 to over 30,000 per month. In 1943, respirators light

[1] Historical Section File No. F/574/H.

type (L/T) were introduced having the following advantages over the GS respirators :—

- (i) lighter weight
- (ii) easy manoeuvrability
- (iii) protection against hydrocyanic acid (AC) and cyanogen chloride (CK)
- (iv) better protection against particulate clouds
- (v) conservation of rubber.

Arrangement was also made for production of 50,000 of L/T respirators per month. By the time the manufacture of these respirators was established hostilities ceased and only a trial batch of 5,000 respirators was made in India. By the end of 1942, deficiencies in units of respirators and essential items had been largely made up. Deficiencies still existed in North Western Army, Central Command and training units generally. Reserves were still non-existent both for formations and GHQ. By May 1943, the field army was complete in initial issues except for some partial deficiencies in the less important oil-skin items. The main deficiency was in capes antigas (75 per cent. deficient). Non-field army units were still totally deficient in items while the field army was partially deficient but were complete in essential items. By October 1943, reserves were in general complete except for ointment (90 per cent. deficient), eye shields (40 per cent. deficient) and certain items of oil-skin clothing especially capes (100 per cent. deficient). In January 1944, it was decided to withdraw all oil-skin clothing from units except for a small training issue and to hold a reserve sufficient to equip 50 per cent. of the field army immediately on the outbreak of chemical warfare. The remainder of the field army was planned to be equipped within six months of chemical warfare starting. This policy automatically abolished the deficiencies in these items and created surplus except in the case of capes antigas.[2]

USER TRIALS

Apart from production of indigenous antigas equipment especially respirators, user trials were carried out to determine the gas tightness of the L/T respirator and the efficiency and robustness of Porton speech valve under moist tropical conditions. The conclusions arrived at during the trials were briefly as follows :—

- (i) Men with small faces (South Indians and possibly Gurkhas) will sometime find it difficult to fit the L/T respirators. They will require a relatively high issue of small sizes, and introduction of an extra small size is necessary.
- (ii) Violent exertion leading to profuse sweating will cause leaks in about 12 per cent. cases, whereas a gas tight-fit is obtained at rest. Better elastic and head harness and careful maintenance should result in fewer leaks.

[2] Historical Section File No. F/601/9086/H.

(iii) The life of the elastic is short.

(iv) In humid conditions, mould growth on the cloth parts and rusting of metal parts rapidly occur if storage is done in poorly ventilated rooms. Mould growth was also observed on the masks. Some of moulds isolated were pathogenic to human beings.[3]

(v) In spite of the markedly greater volume of sound produced by the L/T respirator with Porton speech valve there is nothing to choose between it and the respirator GS so far intelligibility is concerned for normal speech purposes.

(vi) Orders can be given satisfactorily when using the Porton speech valve provided the voice is raised.

(vii) Over wireless telegraphy sets No. 48 there is nothing to choose between the performance of the light weight (L/W) respirator with Porton speech valve and the GS respirator with microphone attachment.

(viii) Over a mile of cable W110 B on an earth return circuit speech on Tele DV, Tele L 10 Line U.C., USA switch-board BD72 and sound powered Tele IA (H and B) the Porton speech valve is satisfactory.[4]

OFFENSIVE WEAPONS

Up to December 1941, there were no arrangements to use gas offensively in India.[5] The gas was to be used only after the enemy initiated chemical warfare. Stocks of offensive weapons were gradually built up mainly by imports. An organisation called Inspectorate of Chemical Warfare Weapons was developed under the Directorate of Armaments in 1942, for the inspection and maintenance of these weapons. This organisation was closed after the war and its responsibilities were divided between Technical Development Establishment (Ammunition) and Indian Mechanical Engineers (Kirkee). It appears that sufficient stocks of gas weapons against the Japanese were not available to wage effective offensive gas warfare. Defensive equipment as already stated above was also deficient.[6]

PHYSIOLOGICAL AND MEDICAL TRIALS

A number of investigations, including trials on the effect of mustard vapour on skin[7], and eyes[8] and effect of lewisite[9] under hot weather conditions, were carried out by the CDRE(I).

[3] Later trials at the Inspectorate of Military Explosives, Kirkee, showed that the exposed fabric in the canvas reinforcing pieces in L/T masks served as nuclei for mould growth. It could be minimised by sandwiching the canvas reinforcing pieces in between rubber sheets at least 0·2 mm. thick.

[4] User Trial Report No. 28—Trial of Light Weight Antigas Respirator.

[5] Historical Section File F/601/9086/H.

[6] Historical Section File F/574/H.

[7] CDRE(I) Report No. 245.

[8] CDRE(I) Report No. 241.

[9] CDRE(I) Note No. 76.

The vapour concentration in skin trials varied between 1 and 20 mg./cu. metre and in eye trials between 1 and 16 mg./cu. metre. Both trials were carried out in hot weather. The results may be summarised as follows :—

Effects on Eyes:

C.T.[10] 12.	Threshold for demonstrable eye effects ; a mild angular conjunctivitis without symptoms.
C.T. 12-30.	An obvious conjunctivitis possibly causing minor degrees of irritation in a few cases. No interference with efficiency.
C.T. 30-60.	Definite palpebral and bulbar conjunctivitis accompanied in a small proportion of cases by slight oedema and transient photophobia. Irritation or soreness of the eyes may be present but short of casualty severity.
C.T. 60-75.	Danger zone. Widespread conjunctivitis frequently accompanied by chemosis and photophobia. Irritation and soreness of the eyes present. A proportion of casualties possible but these are unlikely to remain ineffective for more than seven days.
C.T. 75-90.	A high proportion of serious casualties likely. Such casualties would probably require several weeks treatment.
C.T. 100 or more.	Zone in which 100 per cent. casualties likely.

Effects on Skin:

C.T. 60.	Threshold for demonstrable skin lesions.
C.T. 60-120.	Varying degrees of erythema of the skin accompanied by some itching and irritation. Non-casualty.
C.T. 120-160.	Erythema of clothed and unclothed areas of the skin which may proceed to desquamation of the superficial epithelium of sub-casualty severity but may require treatment in the medical inspection room or RAP.
C.T. 160-200.	Danger zone. High percentage of casualties possible. Liable to be serious requiring evacuation and hospital treatment.
C.T. 200 or over	Casualty zone. Most men exposed liable to become casualties.

These experiments showed that the eye lesions of any particular degree of severity, will result under tropical conditions, from exposure to a C.T. somewhat lower than that required to produce the same result under cool conditions. During trials to observe the effect of mustard on eyes it was also seen that some observers exposed to C.Ts of 60 or above on the second or third day after exposure complained of huskiness or partial loss of voice which persisted for about four to five days.

[10] C.T. is a product in which C represents the vapour concentration exposed in mg./cu. metre, and T is the duration of the exposure in minutes.

The important conclusions reached from the trials on effect of mustard vapour on skin were summarised as follows—"Actual casualties resulted from exposure to a C.T. of 62. For defensive purposes a C.T. of 120 should be taken as the maximum for safety and a C.T. of 160 or over as coming within the possible casualty range. When atmospheric conditions are such that the entire skin surface is freely perspiring, lesions tend to be of uniform severity wherever they occur. Under cooler and drier conditions the most severe lesions tend to occur on areas of the body normally sweating such as the crutch and axillae and the scrotal lesion usually determines the man becoming a casualty".

Trials on the skin burning power of lewisite vapour were of an *ad hoc* nature but demonstrated that in warm humid climate lewisite vapour is less effective than mustard gas vapour. The general conclusions were that "while it would not be justifiable to draw a firm conclusion from the rather variable results obtained in only a few experiments using very small groups of subjects, there is fair evidence that lewisite vapour is relatively ineffective in causing casualties in a warm humid climate. In such conditions it is probable that a dosage of at least 1,000 mg. min/m^3 would be required to ensure casualties from skin burns among men wearing respirators, shorts and shirt. Men wearing impregnated drill trousers and cellular blouse and applying antigas ointment prophylactically at half hourly interval would not be seriously affected by even higher dosage. In addition to the inferior aggressiveness of lewisite vapour in these conditions as compared with mustard gas vapour, a high dosage of lewisite vapour is less likely to be attained in the field. It would, therefore, appear reasonable to conclude that lewisite is not a suitable vesicant agent for use in warm humid climates".

Reference may also be made to two interesting reports based on various trials, viz., the appearances and treatment of mustard gas burns of the skin under Indian conditions,[11] and clinical aspects and treatment of hand burns due to mustard gas.[12] They are reproduced in Appendices 'A' and 'B'.

GAS CASUALTIES

Gas was not used by the Japanese in India-Burma theatre and there was no occasion for the Allies to retaliate with weapons of gas warfare. Some gas casualties, however, were met with during shell trials and during disposal of the mustard gas bombs on the cessation of hostilities. The following account gives the summary of the observations made in the North West Frontier Province, Bengal and Assam.

Nowshera: An accidental explosion of a 25 pound BE shell charged with HTV 12 poise occurred near Nowshera. This bomb had been deliberately and illegally removed from the firing range by a villager from Pirpia. The villager died instantaneously. Three others died of contamination within 24 hours. Three women died on the eighth, eleventh and twenty-fourth day after the explosion from the late effects

[11] CDRE (I) Report No. 255-Appendix A.
[12] CDRE (I) Note No. 65-Appendix B.

of untreated mustard burns. Many other villagers including a mortuary attendant who carried out an autopsy on the contaminated body of the first casualty also got burns of varied intensity. Out of four patients subsequently admitted to IMH Nowshera, two eventually died. They were lying unattended for several days before admission to hospital.

In general all the four cases had the lower parts of the body more severely affected than the upper parts. It was surmised, from the fact that the buttocks, perineum, thighs, legs and lower abdomen were most severely burned, that much of the contamination of their skin had arisen from lower clothing being contaminated by squatting on the splashed area round the crater, or by a heavy vapour concentration rising and affecting the lower parts near the ground more than the upper parts of the body. All these burns were more severe than any produced experimentally.

From these lesions and their courses the following points were noted by the Physiologist, CDRE(I) :—

(i) The buttocks were almost entirely denuded of epidermis, by deep suppurating, moist or scabby, and necrotic burns. The dermis exposed was intensely painful and tender, red, completely devoid of the pigment layer, and discharging freely.

(ii) This severe condition spread forward on to the labia majora, the inner sides of the thighs, outer and inner sides of the legs and dorsum of the feet.

(iii) The upper parts of the body were less affected. The front of the chest, breasts, neck, face and arms were moderately burnt, in some areas causing shedding of the epidermis, in other areas only hyper-pigmentation. The backs of all patients above the waist were least affected of all. In one woman the lower margins of the breasts had ulcerated severely.

(iv) The axillary spaces, popliteal spaces, antecubital fossae, submammary folds, and the abdominal and inguinal folds were little affected, although the tissues around might be almost necrotic. This would be well explained by the occlusion of these folds when the women were in the squatting position.

(v) Vomiting persisted even as late as the sixteenth day in one case, in which the patient eventually died.

(vi) All four women had aphonia which began to clear on the sixteenth day. Two women showed dyspnoea ; both of them ended fatally.

(vii) New flaccid vesicles of a bullous appearance were appearing as late as the seventeenth day.

(viii) One fatal case was more than two months pregnant but she did not sustain abortion ; she was the second most severely burned of the the four, and died 24 days after the incident.

(ix) The palms and the soles showed little sign of the action of mustard.

(x) The general condition of the patients when first seen was very bad indeed ; all had pyrexia and dehydration, were in great pain, and restless, with a harassed and distressed appearance. One was semi-delirious, and another was almost comatose when first seen.

1. Extremely severe necrotic deep burns of buttocks and upper thighs.

2. Moderately burned buttocks.

1. A typical blister on the left forearm.

2. Typical pigmentation blackened areas.
   (i) In the neck, ending abruptly at the points covered by the face-piece and head harness; and
   (ii) Over the hands and arms, ending below the shoulder.

When the condition of the burns had improved the surviving patients looked better and more comfortable, the toxaemia and pyrexia rapidly abating.

(xi) One patient, a girl of 17 years was comatose when admitted from the village to the IMH and died 24 hours after admission, on 27 June 1943, 11 days after the accident. This girl was dreadfully burned, more than half her body area being affected, face, neck, chest, abdomen, perineum, buttocks, thighs and legs being vesicated, scabbed, desquamating or necrotic. A post-mortem was carried out on 28 June 1943 by CDRE(I) staff and she was found to have a right lung pneumonia, gastric inflammation, and extremely inflamed kidneys in addition to the skin conditions.

(xii) The second fatal case, aged 20 years, died after 13 days in hospital, 24 days after the explosion. This woman was very severely burned on the buttocks, perineum, thighs and legs, although not as severely as the fatal case mentioned above. She developed bronchopneumonia on the nineteenth day and died after five more days; autopsy revealed tracheal congestion, severe liver necrosis and a 3/10 pregnancy.

(xiii) One patient, out of four, had a fairly severe ocular condition; in each eye there was an encroaching corneal pannus about 2 mm. across on the sixteenth day, consisting of rugose epithelium with a leash of fine vessels and a thin aura of oedema of the cornea around it, arising on the inner corneoscleral margin and outwards on to the cornea. There was no extensive keratitis, no hypopyon : the scleral conjunctiva was highly injected and the patient was having a certain amount of pain. This eye condition was dissimilar from any known recent lesion of eyes and was actually due to trachoma.

(xiv) The courses of these burns ran very closely similar to those of experimental burns, although the latter have always been milder. The non-fatal cases responded fairly well to treatment, although many indigenous difficulties in the way of treatment were encountered.

(xv) Local treatment consisted of trying to reduce the pain and discharge from the severe areas, and to control infection, first by the use of the hospital sulphonamide ointment and later by the paste used at CDRE(I) (20 per cent. sulphonamide in glycerine). On this the areas improved considerably within a week. Dressings and nursing care of burned areas, in these village women, was a problem of some magnitude.

(xvi) In order to complete the picture of the incident it may be noted that the climate conditions at that time of the year in the area were very hot and dry. The maximum temperatures of the day reached 115° F quite commonly and the minimum night temperatures were about 84° F. The humidity was from 10 per cent. to 40 per cent. depending on the time of the day. There had been no rain in the village from 16 June 1943 up to 28 June 1943.[13]

Gas Bomb Disposal Areas—Dinjam, Dibrugarh and Baligan: The bomb disposal work was carried out by No. 1382 Coy Indian Pioneer Corps. It was estimated that about 95 per cent. of the men became casualties.

[13] Medical Directorate File No. 2003/1/DMS 5 (c).

Their camp was at Baligan about 10 miles from the bomb disposal area at Dinjam. An IAOC officer, a VCO, a sergeant BOR, two havildars and some IAOC personnel were in charge of the prevention and decontamination work. An IAMC orderly trained in antigas duties assisted at the decontamination site daily. The medical officer from Baligan visited the disposal area frequently and for the rest of the time was available at the medical inspection room, Baligan. The bombs in this area were lying free in the ground and were leaking badly. The space, where the bombs were lying, was surrounded by dense jungle. The weather was hot and there was heavy rain at the time which caused a high concentration of mustard vapour. The antigas clothing became unserviceable very soon due to concentration of gas.

The men worked in shifts varying from one-fourth to two hours. They wore respirators and full antigas clothing with the exception of hood. At the end of the shift they walked to decontamination hut and performed personal decontamination. The outer garments were wiped down with swabs dipped in kerosene. The garments were then removed and hung upon a wire. The washing arrangements consisted of buckets of hot water. After washing the men were expected to apply antigas ointment. Number of casualties is shown in Table I.

TABLE I

Mustard gas casualties–gas bomb disposal area—Dinjam.

Categories of troops	Discharges	Transferred to CMH Shillong	Transferred to IMH Alipore	Total admissions
Officer	1	...	...	1
BOR	...	1	...	1
IORs	16	52	13	81
Civilian	1	...	...	1
Total ...	18	53	13 (Eye cases)	84

MINOR CASES TREATED AT MEDICAL INSPECTION ROOM, BALIGAN

There were 13 cases of conjunctivitis due to excessive concentration of vapour in the jungle surrounded area. Captain C. F. A. Cummins investigated 49 cases at CMH Shillong. The average time before the burn was noticed was about three and a half hours. The majority of the men noticed the burn within two hours and the minority noticed them from three to fourteen hours. The first symptom noticed was invariably itching at the affected site.

CLINICAL OBSERVATIONS

Captain Cummins made the following observations :—

" The general condition of all the patients on admission was very good. The men with the more severe burns had mostly slightly raised temperatures and pulse, but on the whole they had travelled the 412 miles by road and rail from Dibrugarh very well ".

The smell of the dressings on arrival was in all cases very offensive; however, the underlying burn was always comparatively clean.

The burns had been dusted with sulphathiazole powder, and then dressed with vaseline gauze, but these dressings had of course not been changed for two or three days because of the journey.

Considering the large area of the burn in many cases, pain was conspicuously slight, although oedema of the limb, or area underlying the larger burns, was great. This was particularly noticeable in the genital area.

The degree of burn varied from erythema to second degree of burns. No third degree burns, i.e., complete destruction of all layers of the skin were seen. Distribution and severity of the burns collated from one group of cases from their medical case sheets are given in Table II.

It will be seen that the genitals, the feet and the hands in the order stated were the most seriously affected parts. Balanitis was common in the uncircumcised. The blisters looked dirty and were all partially collapsed and had a thick roof of dead skin. The underlying burnt area had a peculiar stippled appearance as if the skin pigment had been removed from the small circular areas at the site of hair follicles.

TREATMENT ADOPTED

General : The majority of cases were confined to bed for periods varying from three to six weeks. This was necessary as the lower extremity burns cases developed more oedema if they were ambulant before the burn was completely healed. Five cases, whose condition was poor, and whose temperature was rising to 102°F. or more, received a course of parenteral penicillin 30,000 IU three hourly for three days, which rapidly improved their general condition. Three other cases received a course of 35 g. of sulphathiazole.

Local : The dead skin was gently removed and the raw area cleaned free of pus with hydrogen-peroxide, followed by normal saline. The whole area was then frosted with sulphathiazole powder, and covered with vaseline gauze.

Balanitis : Nine uncircumcised cases with severe balanitis required a dorsal slit. This was performed under intravenous pentothal anaesthesia. In all of these cases the oedema of the prepuce was so great that considerable difficulty was found in inserting the tip of the scissors between the glans and the prepuce. The scissor cut was in the midline

TABLE II

Distribution and severity of the burns collated from one group of cases from their medical case sheets.

Serial number.	Site of burn.	*Average number of days in hospital.	Erythema, but no peeling.		Second degree, i.e., blistering, but healing within ten days.		Second degree, i.e., blistering, but taking over ten days to heal.		Total degrees of severity in all cases. +
			Number of cases.	Degrees of severity. +	Number of cases.	Degrees of severity. +	Number of cases.	Degrees of severity. +	
1.	Face and head ...	10½ days	—	—	2	4	—	—	4
2.	Neck	17-3/7 days	1	1	5	10	1	3	14
3.	Hands and forearms ...	14-3/5 days	2	2	7	14	1	3	19
4.	Upper arms ...	14½ days	—	—	3	6	—	—	6
5.	Chest	20-3/5 days	1	1	8	16	1	3	20
6.	Abdomen ...	23⅓ days	1	1	2	4	—	—	5
7.	Genitals ...	16-11/13 days	—	—	4	8	9	27	35
8.	Thighs ...	15-3/14 days	4	4	8	16	2	6	26
9.	Feet	16¾ days	2	2	11	22	3	9	33
10.	Legs	12⅔ days	2	2	1	2	—	—	4
	Total ...	16-50/81 days	13	13	51	102	17	51	166

*The average has been standardised with reference to the number of cases in each type.
+Degrees of severity of burn have been obtained on the following basis :—
(1) Erythema—least severe and is, therefore, allotted one degree.
(2) Second degree, i.e., blistering, but healing within ten days—more severe than (1) and is, therefore, given two degrees.
(3) Second degree, i.e., blistering, but taking over ten days to heal—most severe of the three and, therefore, is given three degrees.

dorsally, and extended right back beyond the corona as far as possible. Bleeding was slight, and in no case it was necessary to ligature a blood vessel. The penis was dressed with vaseline gauze, and on return to the ward, supported upon a strip of four inch elastoplast stretched across the thighs. The latter measure was not used in the first two cases, and the post-operative oedema became much greater, while in the remaining cases it subsided rapidly. The performance of a dorsal slit brought about a rapid improvement in the general condition, and the temperature was usually down to normal the following day. The balanitis, *per se*, was usually cured by the tenth day after dorsal slit, but the cut prepuce took about 30 days to heal. The oedema of the frenal area of the prepuce, however, persisted much longer, and had not disappeared at the

time of formal circumcision. Circumcision was performed as soon as the dorsal slit wound had healed and the surrounding area was clean.[14]

GAS BOMB DISPOSAL AT ONDAL

Lieut.-Colonel J. H. Bowie, IMS and Mr. F. E. Crofts, IOS investigated cases at Ondal. Their observations are given below :—

All pioneers who had worked in the gas disposal area had been casualties. The sick in line numbered 30, of these 17 had blisters on the arms and/or legs. A further six showed vesicular lesions on the genitals. The remaining seven were under treatment for pigmented desquamating mustard dermatitis.

DETAILED REASONS FOR THE HIGH CASUALTY RATE

The main cause of the casualties was the lack of sufficient personnel for the efficient performance of the work in the hot weather. The number of casualties increased out of all proportion with the reduction in personnel available with the necessary increase in the daily rate of bombs recovered per man and with the advent of the hot weather. The casualties and their causes are divided into two groups :—

(a) *Blisters Caused by Contact with Liquid:* More than 50 per cent. of the sick (70 per cent. of those unfit for any duty whatsoever) were of this type. The blisters were due to disregard of personal antigas precautions. In turn this was due to exhaustion.

Collapsed, insensible and heavily contaminated men were extremely difficult to deal with in this climate ; first aid was particularly dangerous to all concerned when the only individuals available were themselves exhausted and heavily contaminated.

(b) *Vesiculation (Scrotal) and Dermatitis Caused by Exposure to Vapour:* On account of the few persons available for bomb recovery, the men had been exposed to extremely high vapour concentrations for excessively long periods daily over seven weeks. Minor contributory factors might have been the open trouser leg, the absence of a hood and the use of excessive amount of kerosene oil for decontamination during the period of work.

All cases showed a dull, coal-black pigmentation of the skin. The pigmentation was most intense round the neck and over the hands and feet in the glove and sock area. The palms of the hands and the soles of the feet were not pigmented. In the neck the pigmentation extended up into the scalp and over the ears but abruptly ended in a linear demarcation where the skin had been protected by the gas mask and the head harness. The colour extended downwards from the base of the neck over the whole front of the chest and between the shoulder blades.

[14] Medical Directorate File No. 2003/1/DMS-5(c).

In spite of the use of protective ointment (AG No. 6), the blackness of the skin over the neck was as deep in colour as that in the glove and sock areas.

In every case the pigmentation was present and was most intense in the neck, glove and sock areas, but in the majority of cases it spread, less intensely, up the leg to the thigh, over the arms towards the shoulder and downwards from the neck over the front and back of the chest to the upper abdomen.

In every case the area of the face covered by the respirator and the area between the navel and the pubis were pale in comparison with the rest of the body.

In about half the men there was a marked desquamation in one or more of the pigmented areas ; in these cases, this was most evident over the genitals where the skin on the lower aspect of the scrotum was usually broken.

In no case was any lesion of the armpit present other than desquamation of the skin.[15]

[15] Report on disposal of aircraft, bombs and charged mustard at Ondal by Lieut.-Colonel J. H. Bowie, IMS. and Mr. F. E. Crofts, IOS.

APPENDIX A

The Appearances and Treatment of Mustard Gas Burns of the Skin under Indian Conditions

GENERAL SUMMARY

This report[1] was submitted in order to bring forward certain medical aspects of the mustard gas lesions produced during physiological research on vesicant gases as carried out under Indian climatic conditions.

The report deals with the appearances, symptomatology, treatment and prognosis of mustard gas burns of skin resulting from experimental work carried out with Indian and British volunteer military observers at CDRE(I) from 1942 onwards.

The differences in appearances and symptoms of these lesions from those produced in temperate climates, and the added difficulties of treatment under Indian conditions are mentioned, and a brief comparison with the effects of lewisite is given.

The value of the sulphonamide and gentian violet series of preparations is stressed and the importance of early treatment of the lesions in the hopes of preventing the infections which hot weather conditions in India tend to induce, is also emphasised. The scrotal skin and other vulnerable areas need special care in observation and treatment ; the presence of skin complaints due to the heat and humidity of the hot weather makes care of the lesions and the whole of the skin after exposure more urgent than under cooler conditions. Formulae in use, are described and listed in an annexure to this Appendix.

INTRODUCTION

From April 1942 to July 1943, a large number of experimental mustard gas burns, of intensities varying from mild to severe have been produced during experiments on observers attached to CDRE(I). Since these volunteers remained at the CDRE (I) for a period of one month, opportunity occurred for the investigation of their courses, and their treatment by different methods. These burns occurred under controlled experimental conditions.

Some of the lesions produced were very small (a few millimeters in diameter), others were sufficiently severe and extensive (e.g., vesication of the entire area of a back) to necessitate hospitalisation. Generally speaking, the arms, back and occasionally the legs were mostly affected; opportunities arose, however, to study the treatment of mustard burns of the trunk, axillae, perineum and genitalia; and these were treated under very hot, distressing climatic conditions, as well as under cooler, almost European conditions.

[1] CDRE(I) Report No. 255.

DESCRIPTION OF THE APPEARANCES OF THE LESIONS

The various stages or end-results due to the action of mustard gas on skin, either from vapour or from liquid droplets on the bare skin or through clothing may be briefly described as follows.

First Stage (*one hour to four days in developing*), *Erythema of the Skin without Swelling or Blistering :* This may vary from pale pink to bright scarlet in different lesions ; in the darker types of skin the erythema gradually turns to pigmentation after five to seven days. This erythema is symptomless, except for itching, in its later stages. It may, however, proceed to the next stage.

Second Stage (*one hour to six days in developing*), *Erythema with a Palpable Thickening* (*Oedema*) *of the Skin :* This condition also is normally almost symptomless, but if severe or in the sensitive areas, may break down to a dry or moist exudative lesion, which may become infected. It is usually followed within a few days by pigmentation and irritation. This stage also may proceed further.

Third Stage (*two hours to six to eight days in developing*), *Pinpoint* (*Minor*) *or Crepe-rubber Vesication :* Pinpoint (minor) vesication may supervene on the above areas, due to simple localised continuation of the exudative process. The oedematous skin develops minute vesicles (1-2 mm. diameter) which may abate in a few days, or be chafed and infected, or proceed to coalesce to form one or more vesicles of large size. One form of this condition has an appearance which has lead to calling it ' crepe-rubber vesication '.

Fourth Stage (*four hours to eight to ten days in developing*), *True Vesication :* True vesication results from the confluence of these minor vesicles : large, domed thin walled blisters appear at any stage from the first to the tenth day, and usually become tense, eventually to burst and ooze serum, or at times remaining raised, and filled with a gelatinous yellow serum clot which cannot be drained off. The blisters are fragile, and under active service conditions may almost all be broken on first examination. They arise from an area of skin which is swollen and reddened for some distance around.

Fifth Stage (*which may underlie the fourth stage*) *Skin Necrosis :* Subepithelial devitalisation of the dermis is seen only in severe cases of liquid or vapour burns, and is followed by a very slow healing of the necrotic area. The tissues below the blister are of a yellowish grey tinge and of blotting paper appearance. Scarring follows healing of the lesion.

In a vapour or liquid contaminated patient any or all of these stages of burning may be seen in different areas of the body. For example a moderately severe contamination of the back of a man's shirt may produce erythema of the chest sides, palpable thickening and redness of the posterior axillary fold area, with patchy minor vesication of the skin below the contaminated area ; confluence in the prominent areas of the shoulder blades may form vesicles, some of which, if severe, may heal slowly with a scar.

SYMPTOMATOLOGY

In mild cases of burns only a slight discomfort is present in the area of the lesion ; even a small and tense blister is almost symptomless, being less painful than an equivalent thermal burn. Extensively burned areas, such as a whole limb or an entire back, result in considerable pain due to the tenseness of vesicles. There is tight oedema of the skin and much swelling of the entire area, with some malaise, transient reactionary pyrexia of low degree, and a natural reluctance to use the affected parts of the body. This painful stage usually lasts in a severe case for four or five days and then abates quickly.

There is in such a case of mustard burns none of the great ' shock ' which would be associated with a thermal burn of equal area, and the pain and incapacitation are considerably less with chemical than thermal burns. Sometimes the condition is at its height of severity within two days, sometimes (especially with burns due to low vapour concentrations) not for seven days or more.

After the first three to five days, the painful discomfort gives place to an intense intractable irritation over the entire area affected, the severity of which is one of the most constant complaints among all the cases treated. Its constant presence for days or weeks and the difficulty of allaying it make this irritation an important feature of the course of these burns. It is naturally worse under hot humid conditions than in temperate climates. It results frequently in mutilation of the areas by scratching, in the removal of fragile epidermis, and in loosening of dressings ; it greatly increases the liability to infection, when left untreated, and often causes considerable loss of sleep. It seems that only mustard gas and the nitrogenous vesicants cause this delayed and severe itching. Lewisite and the other arsenicals cause only a slight early irritation.

On most skins, pigmentation is another late result of mustard burns ; only very fair skins fail to develop this. The hue of most mildly burnt areas gradually changes from a bright to a dusky red, then reddish-violet, gradually passing through various tones of lavender and brown to an eventual moderately deep brownish-black pigmentation. Its intensity varies with the severity of the lesion, and its hues with the individual. It passes off in a few weeks and needs no treatment. Where vesication has occurred, or desquamation has loosened the pigment bearing layer of the epidermis, the skin remains pale. Generally speaking, therefore, severely burned areas will be pale, almost white centrally (possibly with thin scarring), and darkly pigmented peripherally. This is a marked feature in the dark skinned races of India and may cause some alarm ; in most cases, however, these depigmented areas gradually recover most of their pigmentation.

The above types of results from burns may be additionally complicated by such factors as the chafing of clothing and equipment, infection by scratching or by the spread to the burns of an already existing skin complaint, especially in the hot humid months of the year in India,

when the response to aseptic treatment is low, and the probability of infection high.

VESICANT BURNS UNDER INDIAN CLIMATIC CONDITIONS

There are certain differences in the appearance and course of mustard burns as seen under Indian conditions from those seen under European climatic conditions. In India the exposure needed to produce a burn is slightly less (i.e., a lower CT is needed) and the visible results of the vesicant arise considerably quicker. Both these facts are probably due to the climatic heat causing added moistness and hence added permeability of the skin, with a frequently higher skin temperature (especially when the skin is exposed to the sun) which facilitates absorption of the vesicant molecules.

The course of such burns in India is made worse by the frequently profuse sweating, especially in the flexures of the body ; by concurrent skin infections, such as prickly heat, epidermophytosis, pyogenic rashes, and other hot weather rashes of common occurrence, but of little understood aetiology. Infection is more common and its prevention more important but likewise more difficult; good skin hygiene in the active service areas is a difficult state to attain.

Irritation, too, although notable under all conditions following mustard burns, is severe when the weather is hot and humid; especially when the burn is of skin which was itchy even before hand. Also the dressings of a large burned area must be made to suit the climatic conditions to a certain extent, as well as the injured skin condition.

TREATMENT OF THE LESIONS

In general it will be appreciated that there are certain aspects of added interest in the treatment of mustard burns under these severe climatic conditions. There may exist in any single case of mustard burns, a considerable variety of skin conditions to treat and the lines of treatment which have been recommended at various times are very numerous. At CDRE(I), however, there has gradually arisen a series of preferences in treatment, some of which are possibly largely suitable for Indian conditions, and of which the following is a brief summary. Formulae for the preparations mentioned are given in the annexure.

Treatment of Simple Erythema: Where erythema is the maximal and end-result of a burn, in most cases it requires no treatment, except that of symptomatic type, e.g., cooling lotions, and anti-pruritic lotions. Erythema affecting flexures needs careful watching, for although the redness itself may not increase yet there is no rest for the skin and one may have to treat rough, cracked, excoriated skin, or even oozing and tender areas.

For these the chief consideration is to lessen skin movement by joint or limb restriction, if necessary, to keep the skin free from infection, and to lessen its dry painful state. Here calamine liniment, acriflavine emulsion or jelly, castor oil—zinc oxide cream or liquid paraffin, for the

most part is used. If the area is suspected of superficial infection (by its appearances or tenderness) for the first few days, it may be dressed with a cream of sulphanilamide in glycerine (plus zinc oxide for thickening) under a jaconet or oil-silk cover, and later on by the above mentioned dressings. Eventually the skin becomes renewed and supple, and dusting powder only is then applied.

Where erythema comes on very early after contamination, it will probably progress to further stages ; it is best then to anticipate this by applying the treatment of these later stages, in the hopes of lessening their severity and of avoiding delay in treatment.

Treatment of Erythema with Swelling: This stage is generally painful when the area affected is large and the oedema can fill the underlying tissues. It is hot also, and itches, so that some interference with sleep is common in extensive burns. Morphia $\frac{1}{4}$ grain under the tongue is often suitable for occasional use in severe cases.

The lesion itself may be treated with cool dressings of calamine lotion, refreshed periodically, or with dressings of hypertonic saline or sodium sulphate solution, 5 to 10 per cent. Oily dressings are not usually much comfortable, although there is some favour given to liquid paraffin or sterile cod liver oil by workers in the United Kingdom. However, these dressings are not very comfortable under Indian hot weather condition.

The oedema subsides by the second to sixth day and the lesion may then be treated as above especially where flexures are affected. Skin damage is naturally more extensive, and shedding of the epidermis over the affected areas will commonly occur, along with intense itching. Scarring will not occur, and about 12 to 28 days only will be needed (if the condition has been uncomplicated by infection or vesication) for almost complete freedom from symptoms to eventuate.

This oedematous redness and heat may be the precursor of an oncoming vesication, and where it arises soon after contamination, it is best to anticipate vesication's problems by thoroughly cleaning the skin (with ether soap and spirit) before applying the above treatment and to ensure as far as possible that adequate protection to blisters is afforded by a large sterile dressing applied while the skin is in an inflamed but unvesicated state.

Treatment of Minor and 'Crepe-rubber' Vesication : The interesting condition of crepe-rubber vesication, in which the epidermis is locally lifted by exudation but still bound down at the hair follicles, gives an appearance much like a magnified 'peau d'orange'. It is difficult to treat, since the tenseness of the exudation is not yet capable of being relieved by blister incision, as the minor vesicles are so small. Hypertonic dressings with an anti-bacterial action are applied to the previously cleaned skin, and the best of all is the sulphanilamide, zinc oxide and glycerine cream mentioned above. This is very effective in ensuring skin health and cleanliness, tends to lessen pain, is easy to apply, painless to remove, and has no contra-indications except the

frequent difficulty of obtaining its constituents, and the fact that if it is kept occluded by jaconet for too long (more than four days), it may tend to induce a pustular dermatitis around the lesion. This does not arise if the jaconet left off early or if, as is the case at CDRE(I), the dressing is regarded as one for the initial stages of the lesion, and substituted by another type after two or three days.

Alternative dressings for crepe-rubber vesication include sterile liquid paraffin, saline compresses (when they dry these latter often irritate), acriflavine emulsion, calamine lotion (to which is often added about 10 per cent. of sulphanilamide) or occasionally, where the complaint of discomfort is slight and the condition mild, sulphanilamide powder alone or with equal parts of talc and starch or zinc oxide may be dusted over the area.

If the area is large, discomfort from this stage is severe, and sedative and analgesic drugs are quite important in treatment. It is necessary then to devote some general treatment to the patient, who may have a low fever for the first day or two, feel unwell, and have much pain in the affected part. If the area concerned is extensive, he may have to lie in bed for a few days or longer pending on the areas involved, and the course of healing is about three weeks during which period the loosened epidermis thins and breaks and often leaves the raw dermis exposed. The lesions may then receive the same treatment as that of the next stage, in which the exudative process has merely progressed to maturity.

Treatment of Fully Developed Vesication : Here the exudation has formed localised domed blisters, large or small, tense or slack, arising from an area of swollen erythema. These blisters are thin walled and will almost all be broken when they appear for treatment on active service, thus settling the problem of whether or not to prick them as first aid treatment. Blisters may, however, appear as late as the twelfth day, while a man is in hospital, so the early treatment of vesicles is important.

The procedure at the CDRE(I) for the initial treatment of blisters was to cleanse the skin as perfectly as its tenderness and circumstances permitted and then to incise the lower edge of the blister and drain off the fluid from it with the help of a little pressure. Sometimes the exudate had coagulated and could not be drained off completely ; these should not be interfered with further. Serous exudation carries on for at least 24 hours after the vesicles arise and this precludes the early use of coagulant types of dressing, such as will be mentioned later. For the first 24-48 hours after vesication, the treatment adopted was that the epidermis was encouraged to remain over the affected area, and was not removed unless it had become rolled up, displaced or dirty by prior incident ; the whole area was covered by a dressing of sulphanilamide, zinc oxide and glycerine cream on lint gauze, which was covered over with jaconet and bandaged or otherwise retained in position. Cotton wool was only used when essential for the padding of prominences. Hot bulky dressings were avoided and adhesive tape was not used where the skin was affected by burns, as its removal will not only be

painful but may also remove epidermis. The dressing was left on for 24 hours ; if the patient seemed ill, had any pyrexia, severe pain, or if the area affected was at all involved in locomotion, he had to lie in bed. An alternative local dressings which may be used is amyl salicylate, a pleasant oily liquid applied undiluted on gauze soaked in it, with the whole dressing covered by jaconet. Sterile liquid paraffin and sterile hardened peanut oil have also been recommended, their chief virtue being their bland and protective nature. Of all these the most suitable is the first mentioned cream, which has given excellent results in the CDRE(I). After 48 hours of this type of dressing, although the vesication will probably have increased in size and severity from when it was first seen, due to the insidious nature of all vesicants, yet the area will be clean and of healthy appearance, oozing will have ceased, and the affected area will be less tender.

The continued treatment and care of the area may now be undertaken. This involves the use of an occluding dressing of some type. The use of the tannic acid containing group of coagulants has been widely advocated, but in the CDRE(I) these were not especially satisfactory. These harden quickly on the skin, and in hardening contract and cause pressure and blanching of tissues already devitalised and in no state to thrive on further pressure. These cause pain after a time and the patient does not like them. These have no superlative virtues, and their chief function, that of serum coagulation, is not at this period necessary. This applies to tánnaf, tannaflavine and tannic acid itself, all of which have been tried.

Gentian violet jelly (1 per cent. dye), made up with glycerine and mucilage of tragacanth, has long been used in the continued treatment of small or large vesicated areas. It is very comfortable for the patient, easy to make and apply, very occlusive and antibacterial and the moderate eschar, thus formed, peels off with little trouble after ten or fifteen days, varying with the depth of the lesion. It is applied to the cleaned area whether the epidermis is in place or not (after three changes of initial dressing the epidermis is usually displaced, but not needing removal) with a spatula, in a thick smear, and its surface dried either by laying thin gauze or cotton wool over it, or merely by saturating the outer layer with a coat of dusting powder containing sulphanilamide or by the assistance of a hot air hair-dryer. The area is daily resmeared with the jelly or painted with 1 per cent. gentian violet lotion, as needed, and on this treatment all straight-forward burns of the non-flexure areas do well. A layer of sulphanilamide powder is often dusted over the lesion before these jellies are applied for the first time.

'Triple dye' jelly is perhaps slightly more antibacterial than the single gentian violet jelly, and since simplicity of dressing is often worthy of adoption some superficial types of shallow vesicated areas may be satisfactorily and safely occluded by regular dusting with sulphanilamide powder, with a gauze dressing added for protection.

After-treatment of the newly healed skin, which may be irritable and tender for sometime, should consist of an occasional application of a 'cold cream' and later of dusting powder only.

Treatment of Infected Lesions : Vesicant-affected tissues are very prone to infection because of the devitalisation of the cells below. Under the hot and humid conditions of the summer months in places like Burma, South East India, and Assam, the health of skin is at a very low ebb, and conditions like prickly heat, epidermophytosis, boils, impetigo and infective rashes are common. Infection of blisters may, therefore, be expected right from the start, and should be anticipated in treatment. At the CDRE(I) the value of sulphanilamide and allied chemicals had been proved both for local application and also for the treatment of any generalised infection. Certainly the sulphanilamide-glycerine cream used there had rapidly improved all infected lesions to which it had been applied, and within three days pain and inflammation had largely disappeared, from lesions which previously were swollen, 'angry' and causing local lymphadenitis. So much so that it often proved possible to follow up with the occlusive treatment (i.e., gentian violet jelly) after a few days. Other dressings, commonly used for infected lesions, included hypertonic salines or antiphlogistine, and for small lesions, elastoplast for a few days.

Such lesions are often found to be deeper and more slow in healing than the uninfected lesion ; they do well on acriflavine jelly as a follow-up dressing. Pustular dermatitis and the pustular form of prickly heat (for want of more accurate dermatological terms) which are very common fore-runners of infection, respond well to 1 per cent. silver nitrate lotion in spirit or 1 : 1000 mercuric perchloride, or 1 per cent. gentian violet or brilliant green lotion, applied twice daily to a wide-spread area around and over the lesion if necessary.

Treatment of the Sensitive Areas : By this term is meant those parts of the body whose skin, by *virtue* of its anatomical disposition or physiological stresses, is rendered particularly prone to movement, stretching, pressure, moistness or difficult hygiene, and which is thereby rendered likely to sensitivity, infection, and a more slow healing than the other parts of the body. Such areas are the scrotum, penis, perineum, pubic region, back of the knees, front of the elbows, axillary folds, neck folds and chin. All these situations are apt to cause trouble even in an otherwise mild case of generalised erythema due to mustard vapour, and should be watched carefully. In the early stages of erythema and itching, powder or cooling lotions containing sulphanilamide may be used freely. If infection occurs and the skin health deteriorates, castor oil—zinc oxide cream, acriflavine emulsion or jelly, sterile liquid paraffin, or gentian violet lotion followed by an oily bland dressing, should be applied to the areas concerned, and local measures taken for hygiene and rest, such as a scrotal suspensor, bandage, arm sling, or even rest in bed. (The preceding para is closely connected with the sensitive areas, infection often resulting, particularly in the moist flexures). Healing is slower, and various minor measures may be necessary to treat symptoms in various parts of the body, especially the genitalia. Nursing of the perineum, genitalia, and pressure points needs careful attention. The scrotal skin is many times more sensitive and vulnerable than any other area of the body. Recent cases have confirmed a similar sensitivity of the female perineal skin.

Irritation : This is a serious and complicating symptom. It is best treated by repeated applications of sterile lotion of a calamine type with a little spirit vini rect. (10 per cent.) to increase cooling, and a small amount of menthol or carbolic acid to help to allay irritation as far as possible. This action is, however, very temporary. Gloves may be worn at night and sedatives administered. Benzyl alcohol lotions (10-20 per cent.) have been recommended and are useful, but are not available generally and their action is also temporary. Light dressings, and the provision of readily available supply of cooling lotion for the area, all help to lessen the irritation. Irritation starts early and may last for many weeks ; it is a test not only of treatment, but also of the patient's self control.

General Condition : Severely burned patients are often very miserable and depressed and in considerable discomfort, which must be experienced to be properly realised. The choice of a comfortable and well fitting dressing and the correct mental attitude of confident reassurance towards their injuries and themselves are important.

Prognosis for the Burned Areas : The ultimate outlook for skin burns is very good ; there is less scarring than in the case of thermal burns. It is only seen in deeper vapour and liquid burns. Pigmentation and itching eventually disappear. The chief residual disability is that the patient has been rendered more sensitive to mustard gas, and subsequently more severe burns may occur with lesser exposures.

THE EFFECT OF LEWISITE ON SKIN

Lewisite is very highly toxic after it has been absorbed through the skin ; the lethal dose for a man is probably less than $1\frac{1}{2}$ cc. when spread on the skin in the form of drops. Death may result early (within 36 hours) from lewisite 'shock' or later, associated with arsenical poisoning from the 30 per cent. arsenic in the lewisite.

Lewisite burns have an appearance somewhat similar to those due to mustard, except that coalescence is less marked and erythema more localised ; differences between the two are frequently difficult to determine, and although perfectly defined examples do occur experimentally under war conditions, yet these are unlikely to be seen. However, lewisite burns come on more quickly (in about one-third to one-half of the time for mustard). The liquid drops sting and burn on the skin, and the vapour where in strong concentration, also stings. Irritation is present only for about 24 hours or less, and pigmentation does not occur to anything like the same extent ; these points are of some value in deciding the nature of the burns. Mixtures of mustard and lewisite combine the unpleasant characteristics of the two gases.

Treatment of the Lewisite Lesions : It is largely similar to that for mustard burns. Early incision and drainage of blisters as was previously recommended is not considered necessary. Liquid lewisite lesions penetrate deeply into skin, with extensive tissue devitalisation ; therefore, the liability to infection necrosis and sloughing is high, and the necessity for anticipating these factors is urgent. This is especially true

under hot and humid weather conditions in India which induce a pathological course and a difficulty in ensuring sterility which is not seen under temperate conditions. The 'initial' and 'continued' treatments are adopted for lewisite vesication just as for mustard vesication, and if the lesions can be treated aseptically early in their course, lewisite burned areas heal well, though slower and with more scarring than mustard burned areas show. No chances should be taken and dressings must be continued until new epidermis has developed over the entire area.

CONCLUSION

The general impression, which has been received from the treatment and study of these experimentally produced vesicant burns, has been that healing, even under adverse climatic conditions, is good, and provided infection can be avoided, good healing is almost inevitable. The additional adverse factors of active service, however, with its train of exhaustion, exposure, infections, and necessary lack of early and regular medical attention, must be borne in mind by those who may have such lesions to treat. There is undoubtedly much scope for variation in the treatment of these burns, and no single stereotyped treatment is capable of being recommended to the exclusion of others at the present stage.

ANNEXURE

The following list shows the composition of the preparations recommended for the treatment of mustard lesions in their various stages, as used in the CDRE (I).

1. *Calamine Lotion*

Zinc oxide	...	1000 g.
Calamine (prep.)	...	1000 g.
Sulphanilamide	...	100 g.
Glycerine	...	500 cc.
Spr. Vin. Rec.	...	500 cc.
Water	...	3000 cc.

Note : Sulphanilamide is not essential.

Dilute 1 : 4 for use.

2. *Calamine Liniment.*

Zinc oxide	...	20 g.
Calamine (prep.)	...	20 g.
Olive oil	...	300 cc.
Lime water	...	150 cc.

3. *Glycerine Sulphanilamide and Zinc Oxide Cream.*

Sulphanilamide	...	250 g.
Zinc oxide	...	150 g.
Glycerine	...	600 cc.

4. *Acriflavine Jelly.*

Acriflavine	...	1 g.
Vaseline (white or yellow)	...	500 g.

5. *Gentian Violet Jelly.*

Gentian violet	...	1 g.
Glycerine	...	10 cc.
Mucilage tragacanth		90 cc.

6. *Triple Dye Jelly*

Brilliant green	...	1 g.
Gentian violet	...	1 g.
Acriflavine	...	2 g.
Glycerine	...	10 cc.
Mucilage tragacanth		90 cc.

7. *Acriflavine Emulsion.*

Acriflavine	...	1 g.
Mucilage tragacanth		500 cc.
Liquid paraffin	...	300 cc.
Triethanolamine	...	15 cc.

Note: The latter is an excellent emulsifier, but is not essential.

8. *Zinc Oxide—Castor oil Cream.*

Zinc Oxide	...	qs
Castor Oil	...	qs

Grind the two together, adding the zinc oxide until a smooth cream is obtained.

Note : These compositions are for hot climatic conditions ; for cold weather use of the 'stiffening' agents are slightly reduced.

APPENDIX B

The Clinical Aspects and Treatment of Hand Burns due to Mustard Gas Arising from Trials with Impregnated Pervious Gloves

INTRODUCTION

Trials[1] were carried out at CDRE(I) in an attempt to develop a simple glove capable of preventing, or at least minimising, the effects on the hands of liquid vesicant contamination. During the course of these trials, when various combinations of gloves and ointments antigas were tested, lesions were caused and this note discusses the clinical aspects and treatments of the hand burns produced.

CLINICAL ASPECTS

Distribution and Severity of the Lesions : In all 460 areas were contaminated with DES or HTV(CR) 12p. and 98 vesicated lesions of varying degrees of severity developed. Table I shows the type of lesions and their size distribution.

TABLE I

Types of lesions and their size distribution—mustard gas burns.

Types of lesion	Description	No. of lesions	Number of lesions with average diameter (mm)				
			2–5	6–10	11–15	16–25	26–30
PHV	The lesions consisted of small separate pinhead vesicles 1-2 mm. diameter. ...	4	3	1	...	...	...
CRV	Semi-confluent areas with vesicles 3-6 mm. diameter. The areas had a crepe rubber appearance. ...	3	...	2	1	...	...
V	Domed vesicles usually single but occasionally two or more per area ; deep lesions, ring vesicles with central necrosis.	91	17	38	19	15	2

Development : The data in Table I refer to the terminal state of the lesions, generally arrived at by the third or fourth day. In some

[1] CDRE (I) Note No. 65.

instances, however, maximum severity, to which depth and position of the lesions contributed, was not reached until the seventh or eighth day. With very few exceptions, all the lesions passed through the stages of PHV to CRV before reaching their terminal vesicle stage.

The Effect of Severity on Hand Function : Although it was unusual for lesions (V) of diameter less than 10 mm. to cause any interference with hand function, yet several cases occurred, where the depth or subsequent minor infection of small lesions made grasping sometimes difficult and painful. Lesions of diameter 16 to 25 mm. frequently resulted in partial restriction of local hand movements. This was first associated with the presence of skin oedema for about four days around the lesions. At later stages, increased depth of the lesions, lack of rest for the hand and semi-purulent infection of the hand combined to increase the tenderness of the blistered area.

Infection : One case of severe infection occurred in a British subject who had four vesicles of diameter 16 to 25 mm. on one hand. After five days the surrounding oedema had increased rather than decreased. A sulphanilamide preparation was applied but two days later the ulcerated areas had spread and the subject showed clear signs of sulphanilamide sensitivity. After further treatment with propamidine jelly (0·15 per cent. May and Baker) followed by Na-penicillin applied in solution through the unremoved dressings, healing was eventually complete after 45 days.

Minor infections occurred regularly in the course of the more extensive and deeper forms of the lesions. From the fourth to the seventh day, pain, local redness and tenderness of the areas increased. In the centre of the ulcer a thin, adherent slough of yellowish colour developed accompanied by a peripheral ooze of thin pus. After four to five days of anti-infective treatment, using 10 per cent. sodium sulphate solutions as compresses or propamidine jelly, the slough separated leaving a deep ulcer with little surrounding inflammation. Subsequent progress was slow and healing occurred after two to three weeks from the time of infection leaving a definite pigmented scar.

TREATMENT WITH SPECIFIC PREPARATIONS

Cetavlon (Imperial Chemical Industries) : This detergent bactericide was used for swabbing all blistered areas from 24 hours onward, whenever dressing was carried out. For the minor lesions the preparation was very satisfactory making them less susceptible to infective processes. For the deeper and more extensive blisters, however, more than cetavlon was needed to obviate sepsis or slow healing.

Propamidine Jelly (May and Baker) : This bactericidal jelly was of such value in the relief to an infected and tender area that it could be left *in situ* for two to four days without re-dressing. When used on fairly severe areas at an early stage, sepsis was prevented in most cases.

Penicillin : The sodium salt in solution (200 units/cm.^{3} in saline) was applied to one definitely and severely infected case with favourable

results. Within two days the considerable pain, throbbing, local oedema and discharge had diminished appreciably and healing started. This was the only case treated with penicillin which had only recently arrived.

Vaseline Gauze : Surgical gauze impregnated with sterile yellow vaseline proved to be a very unsuitable dressing for the climatic conditions encountered during the south west monsoon season in South India, although the ease of removal appealed to the patient. The universal sogginess of the ulcer area and surrounding skin led to a tardy epithelialisation and poor healing.

Sodium Sulphate (10 per cent.) Compresses : When the sodium sulphate compresses were applied two or three times daily to ulcers possibly or definitely infected, unhealthy ulcer bases were cleared and the inflammation was reduced. The nursing required and the sogginess of the skin associated with the use of the compresses made them less satisfactory than propamidine or penicillin.

Sulphanilamide : Sulphanilamide powder applied around and on an aspirated or broken blister, was satisfactory for minor and dry lesions. In case with large areas and where discharge from ulcers was present, local signs of the occurrence of irritation or sensitivity were not infrequent. In view of the severity and intractability of sulpha drug skin sensitivity in the tropics, the use of the powder was discontinued.

Dyes, Gentian Violet and Brilliant Green : The local effect of these dyes in aqueous or alcoholic solution was found useful in two ways. In the first place, the bactericidal effect of the dye prevented any minor pustulation of surrounding areas. Secondly, when used in the almost epithelialised stages of healing ulcers, the surface became hardened sufficiently to enable dressing to be discontinued several days earlier than with other preparations. On the other hand, treatment with these dyes in the early stages was followed by rather adverse results on lesions overlying joints, where movement tended to crack or loosen the coagulum with the result that oozing in uncovered lesions occasionally recommenced.

Zinc Oxide/Castor Oil Cream : For minor lesions and the later stages of the more severe lesions this cream proved valuable. It was easy to apply and remove ; it left the skin supple but not soggy, it soaked up minor discharges and could be left in position for two or three days without disadvantage.

CHAPTER XXXI

Dental Service

ORGANISATION AND ADMINISTRATION[1]

Before and during the early years of World War II, the dental service in India catered for British troops only and was manned by officers of Army Dental Corps (ADC). Indian soldiers for dental treatment depended on whatever assistance could be provided by the medical officers in IMHs. The IMS Dental Branch [IMS(D)] was started in 1940 with 12 dental officers. This number subsequently rose to 131. In 1943, the Indian Army Dental Corps (IADC) was formed and all officers of the IMS(D) were either transferred or seconded to it. In the beginning the other rank elements for dental branch were found from the IAMC. From 1946, the IADC other rank cadre was also authorised.

In addition to the already existing military dental centres for British troops eight centres were opened initially in IMHs. Soon after, one dental surgeon with the necessary staff was allotted to every group of two general hospitals ; and four Indian dental units were thus sent to operational areas abroad. By August 1945, by which time the maximum number of units had been raised, there were 84 Indian dental units (including 51 for Indian troops and 33 for British troops) and 29 Indian dental mechanical units.

The administration of dental service in India Command at the GHQ was carried out by the senior ADC officer designated as deputy director dental services (DDDS). By the end of 1942, the appointments of assistant director dental service (ADDS) were authorised in each command.

DENTAL TREATMENT—INDIAN TROOPS

The sick wastage caused by lack of adequate dental treatment was on account of the following main dental diseases : (i) Pyorrhoea. (ii) Dental abscesses. (iii) Caries. (iv) Acute and chronic infections of the gums.

It was decided in 1940 to provide adequate dental treatment to Indian soldiers. VCOs, IORs, and NCs(E) could then be provided such prophylactic treatment as might be considered necessary by the army dental officers, and provided such treatment was undertaken in army dental centres. Supply, renewal or repair of artificial dentures were only authorised to IORs if the general condition of the soldier serving overseas or in the field area was affected by the loss of teeth. Such dentures were to be supplied when approved by the administrative dental officer. In any other circumstances dentures were to be provided only if the Government of India agreed to such provision.

[1] See also volume on *Administration*, chapter V, page 66.

It was anticipated that the amount of dental treatment required for the Indian troops would be relatively very small as compared to the British troops and the dental officers would largely be engaged in carrying out the early treatment of maxillo-facial injuries and providing emergency dental treatment. In actual practice, conditions were found to be very different. The common fallacy that the Indian soldiers have got very good teeth was proved to be wrong. The incidence of dental diseases amongst the Indian troops was over 70 per cent. The dental diseases noticed in them were generally as follows :—

Caries	40 per cent.
Infection of the gums	20 per cent.
Pyorrhoea	10 per cent.
Scaling of the teeth	over 80 per cent.

Most of the Indian soldiers and the new recruits had never seen a dentist prior to their joining the army. The unusual service conditions also aggravated dental disabilities.

DENTAL TREATMENT—BRITISH TROOPS

Dental treatment for British troops employed with Indian Army was usually provided by the RADC officers. But in cases where there was no RADC dental officer, civilian dental surgeons were employed to give the necessary treatment provided the district commanders felt that such employment was absolutely necessary.

The attention of all ranks was periodically drawn towards the necessity of taking great care of their teeth with a view to avoiding needless suffering, sickness and inefficiency. Dental officers gave lectures to soldiers on the principle of oral hygiene and also gave individual instructions to persons when they came up for treatment. Routine periodical inspections were also carried out for all British troops.

Dental treatment was also extended to families of British troops at Government expense provided they could attend the army dental centres. This treatment was given as long as no extra cost for treatment was involved. Supply of artificial dentures was not included in this treatment.

Prior to the outbreak of World War II, no British soldier was sent to the India Command unless he was dentally fit. But this standard could not be maintained after the outbreak of the war as a large number of personnel had to be sent to overseas within a short time.

The term ' dentally fit ' as used for the British troops meant clean and healthy mouth in which all carious teeth had been filled and serious deficiencies of teeth had been made good by the fitting of artificial dentures. The degree of dental treatment carried out depended upon local conditions. The guiding principle was to render the greatest good to the largest number.

Recorded dental treatment given to the Indian and British troops in India from 1941 to 1945 is shown below :—

(a) Teeth filled	1,017,362
(b) Teeth extracted	6,57,501
(c) Gum treatment	48,759
(d) Artificial dentures supplied	38,978

DENTAL TREATMENT—OFFICERS

Prior to 1942, officers of the Indian Army were not entitled to routine dental treatment at Government expense, except when the dental disability was attributed to military service. Indian and British officers and members of the Military Nursing Service on active list were allowed dental treatment at the public expense in an army dental centre provided no additional expense was involved to the state beyond the cost of necessary materials. The supply, renewal and repair of artificial dentures were undertaken on repayment at the rates laid down in *Pay and Allowance Regulations for Army in India, Volume II, Rule* 549. In cases where the dental disability was due to wounds received in action or in the performance of military duty or attributable to military service, the supply, renewal and repair of artificial dentures were undertaken at the state expense.[2]

SOME ASPECTS OF DENTAL TREATMENT PROVIDED

General: The war provided an opportunity to give dental treatment to a large number of adult population. The dental care afforded by the army dental service was far less than what the service wished to provide. Nevertheless, it was an improvement over anything that most of the personnel had experienced in the civil life prior to joining the army. It was an encouraging fact that the dental treatment was accepted by large number of personnel who previously had received nothing but emergency treatment when forced to do so.

Conservative Work: Conservative work was based on methods well known in the dental profession. A small number of acrylic resin inlays were fitted but the material used was found to be not entirely suitable though it had an application in the manufacture of jacket crowns.

Anaesthetic : Local anaesthetic was nearly always used if conditions permitted. Nitrous oxide was the usual general anaesthetic used. Basal narcotics alone or in combination with other inhalation anaesthetics were used for more extensive surgery. The only difficulty which arose was of supply of anaesthetics specially on active service.

Prosthesis: It was difficult to keep pace with the demand for dentures because of the shortage of dental mechanics and suitable equipment. All the denture work was carried out by the British mechanics, as no Indian mechanics were recruited during the war.

[2] A. I. (I) No. 316/1941.

Until early 1942, nearly all dentures were made of vulcanite. A small number of dentures of metal base and a few experimentally in the new acrylic resin were also made. After the capture of Malaya by Japanese a shortage of rubber was inevitable with the result that acrylic resin was introduced in 1942. This material had great advantages over the vulcanite. This had great unit strength, weight for weight, improved appearance and was simple in processing and easy to keep clean.

INFECTIONS OF THE GUM

A large number of Indian troops suffered from mild chronic gingivitis which has little discomfort in the early stages but gradually led to periodontitis and subsequent loosening of the teeth. Percentage of gum infection amongst the Indian troops was higher than the British troops. This was aggravated by the difficulty in procuring *datan* for cleaning teeth which is commonly used by the Indian troops. Use of tooth brushes was encouraged. This was not an authorised issue, and it was not possible for most of the soldiers to use them due to their financial limitations.

ULCERATIVE GINGIVITIS

The incidence of ulcerative gingivitis amongst the Indian troops was remarkably low as compared with the British troops.

Amongst the British troops the incidence of acute ulcerative gingivitis was high. Most of the cases gave a history of recurrence and the paradental condition was usually so bad that on clearing up the gingivitis drastic extractions were necessary to prevent recurrence and general chronic oral sepsis. The usual treatment adopted was as follows :—

Ten per cent. chromic acid was painted between all teeth. This was followed by application of hydrogen-peroxide. This treatment was continued until the condition had fairly improved. Scaling of the teeth was carried out wherever possible in the early stages. In cases, where there was hypertrophy of the gingivae, a week's follow-up course, with glycerine and tannic acid, accompanied by salt massage by the patient was found to be very beneficial in the prevention of recurrences. In certain cases the gingivitis was treated by the continuous use of penicillin lozenges.

Quite a number of surgical removals of teeth was followed by the use of penicillin paste pack in the sockets. The results were very good.

CHAPTER XXXII

Ophthalmology

ADMINISTRATION

The authorised establishment for ophthalmologists in the India Command was eight prior to World War II. They were assigned to commands, and much of their time was spent in touring. In the subsequent development of India Command as a training ground for troops and as a base for operations against the Japanese, the scheme of main and subsidiary eye centres was adopted in 1942. These centres were located at existing hospitals which were chosen with regard both to the anticipated volume of work and also to geographical considerations in outlying areas. The main centres were to be designed and equipped for teaching purposes and staffed by experienced specialists, to whom it was intended that difficult cases should be referred for opinion or for major operations where indicated.

This arrangement remained in operation to a considerable extent throughout the war, though lack of sufficiently experienced ophthalmologists prevented the main centres from filling their role as originally planned. It was moreover necessary to adapt the scheme to fit into the general plan for medical services in India. Provision had to be made for two classes of patients, viz., (i) cases arriving in convoys from operational area outside India, and (ii) local garrison sick. Technical considerations, such as the advisability of concentrating all ophthalmic cases in the same area in one hospital for efficiency in treatment and nursing, and economy in specialist personnel and equipment, had to be reconciled with administrative interests requiring Indian and British cases to be accommodated apart and also the segregation of convoy cases from local garrison sick.

The situation was met by locating the eye departments either in IBGHs, as at Poona, Secunderabad, Lucknow and Karachi, or in garrison hospitals throughout India, or again in certain BGHs temporarily employed on garrison duties. After 1943, some Indian Ophthalmological units (i.e., field units intended for attachment to IGHs), to which no role had been allotted, were utilised temporarily on garrison duties in stations hitherto not adequately covered, such as Madras, Waltair, Chindwara, Agra, Jhansi and Roorkee. The peace time procedure, whereby outlying areas were toured at intervals by specialists, was restricted as far as possible. It was recognised that neither good ophthalmic work was possible in unsuitable surroundings, nor simple treatment could be efficiently carried out on ophthalmic cases when not supervised by the ophthalmic specialist.

Location of different eye centres in August 1945, is given below :—

Armies/Commands	*Garrison Hospitals*	*Base General Hospitals*
North Western Army	IMH, Karachi. CMH, Abbottabad. CMH, Bannu. CMH, Quetta.	No. 6 IBGH, Karachi.
Central Command	BMH, Lahore. IMH, Ferozepore. CMH, Bareilly. CMH, Roorkee (No. 20 Indian Ophthalmic Unit). IMH, Lucknow. IMH, Allahabad (No. 29 Indian Ophthalmic Unit). IMH, Meerut. BMH, Delhi. CMH, Agra (No. 19 Indian Ophthalmic Unit). BMH, Jhansi (No. 17 Indian Ophthalmic Unit). IMH, Jubbulpore. CMH, Chindwara (No. 28 Indian Ophthalmic Unit). No. 60 BGH, Bilaspur.	No. 136 IBGH, Dehra Dun. No. 130 IBGH, Lucknow.
Eastern Command	No. 21 BGH, Calcutta. IMH, Alipore. CMH, Entally (No. 30 Indian Ophthalmic Unit). CMH, Midnapore (No. 12 Indian Ophthalmic Unit). CMH, Ranchi. No 102 BGH, Ramgarh. IMH, Shillong. No. 66 IGH, Manipur Road (No. 8 Indian Ophthalmic Unit).	No. 138 IBGH, Dinapore.
Southern Army	BMH, Deolali Central. IMH, Deolali South. BMH, Colaba. IMH, Bombay. BMH, Poona. IMH, Poona. No. 40 (West African) General Hospital, Aundh. No. 151 (East African) General Hospital, Aundh. No. 18 BGH, Kamaredi. IMH, Trimulgherry. BMH, Bangalore. IMH, Bangalore. IMH, St. Thomas Mt. (No. 13 Indian Ophthalmic Unit). CMH, Coimbatore (No. 7 Indian Ophthalmic Unit). No. 153 (West African) General Hospital, Madanapalle. CMH, Waltair, (No. 21 Indian Ophthalmic Unit).	No. 147 IBGH, Kirkee. No. 137 IBGH, Secunderabad No. 20 BGH, Jalahali. No. 22 Indian Ophthalmic Unit, Avadi.

CONSULTANTS AND ADVISERS

Before 1942, there was no consultant ophthalmologist or adviser in ophthalmology in the India Command and no efficient co-ordination or organisation of the ophthalmic services in the Indian Army. A consultant ophthalmologist was appointed for the Southern Command in 1942, and to his duties were subsequently added that of adviser in ophthalmology, GHQ. Being attached to the Headquarters Southern Army, he was not in touch with the situation at Delhi, and much of the routine work continued to devolve upon the consultant surgeon, India Command. On the arrival in August 1943, of a consultant ophthalmologist to India Command, the post of adviser was abolished. At the close of 1944, the consultant to the Southern Army retired, and this post was also abolished; two part time advisers (one each for the Southern Army and Eastern and Central Commands) were then appointed. The most important function of these advisers, apart from clinical work and consultations on cases referred to them, was that of teaching and reporting on the capacity of trainees. Recommendations for posting of personnel and locations of centres and units, and the control of the issue of ophthalmic equipment, remained the responsibility of the consultant at the GHQ.

RELATIONSHIP WITH THE SEAC

Consultants at the Medical Directorate in India were responsible for the medical services for the forces in Assam and Burma up to the time, when an independent command, the Eleventh Army Group (afterwards ALFSEA) was constituted. An adviser in ophthalmology was appointed to the latter formation early in 1945. Throughout the campaign, India was responsible for meeting requirements as regards units, reinforcements of personnel and supplies and maintenance of equipment.

Until the end of 1943, the ophthalmic cover for the forces in Assam and East Bengal was remarkably thin. Apart from the eye department at the IMH, Shillong there was only one Indian ophthalmic unit (No. 5) in the whole area. Nos. 4 and 6 Indian Ophthalmic Units joined the force at the end of that year, and No. 8 Indian Ophthalmic Unit also began work in Assam in January 1944. During 1944, Nos. 9, 10 and 11 Indian Ophthalmic Units arrived and Nos. 15 and 16 Indian Ophthalmic Units were also arrived in the theatre in 1945. Certain general hospitals with ophthalmic departments were assigned to the Eleventh Army Group during 1944, viz., Nos. 14 and 38 BGHs and No. 49 West African General Hospital. No. 150 East African and No. 152 West African General Hospitals which had ophthalmic departments also arrived. By the middle of 1945, there were 15 eye specialists with equipment working in the ALFSEA. There was, in addition, one mobile RAF ophthalmic unit.

In Ceylon, the eye work was undertaken at No. 35 BGH. The naval cases were cared for at the Royal Naval Auxiliary Hospital, Colombo. The Ceylonese cases were attended to at No. 132 Ceylonese

General Hospital. No. 18 Indian Ophthalmic Unit arrived in Ceylon early in 1945.

Owing to the large area to be covered in India and to the problems of transport encountered in visiting forward areas during active operations, it became increasingly difficult for the consultant ophthalmologist to supervise the clinical work of the ophthalmic surgeons, mostly Indians, working in forward areas. In October 1944, it was suggested to appoint a part time adviser who while normally in charge of an ophthalmic department in an advanced base general hospital should visit forward ophthalmic units, at frequent intervals and keep in touch with the specialists working in them. Early in 1945, a whole time adviser was appointed to Headquarters ALFSEA and the immediate responsibility of the consultant ophthalmologist at the GHQ, thereupon terminated.

PERSONNEL

As already stated, the pre-war establishment of ophthalmic specialists for the India Command authorised a strength of eight ophthalmologists. During the war, this basic establishment was increased to 14 and by combining that number with those on the war establishment of base hospitals in India, a GHQ pool of ophthalmologists was formed in 1943, which by July 1945, provided for 40 appointments. In addition, the number of Indian ophthalmic units (intended for attachment to IGHs in the field) was raised first to 11 and again by the spring of 1945, to 22. In British, African and Ceylonese general hospitals located in the India Command and the SEAC which possessed ophthalmic departments there were 18 ophthalmologists. Finally, three British mobile ophthalmic units were formed by the SEAC in the summer of 1945. Thus, at the close of the war against Japan, establishments in the India Command and the SEAC provided for 83 ophthalmic specialists, excluding the consultant to the India Command and the adviser to the ALFSEA. This actual figure was never attained. The following details give some idea of the growth of the service. In August 1943, there were one Ceylonese, 19 IAMC and 9 RAMC specialists. In August 1945, there were 45 IAMC and 32 RAMC ophthalmologists and one Ceylon Medical Corps ophthalmologist, of whom 19 were in the SEAC. A further six (three from each corps) were allocated to the SEAC under arrangements made for occupying territories recovered from the Japanese at the end of the war.

During 1942-43, it was considered that India was able to provide an adequate number of capable Indian ophthalmologists. A number of British specialists were, therefore, withdrawn for service elsewhere. From 1943 to the summer of 1945, all but one of the RAMC ophthalmologists reinforcements were on the strength of new units arriving in India to support increasing commitments. The number of Indian ophthalmologists was gradually increased partly by training and grading general duty medical officers. Of the more experienced Indian ophthalmologists of military age the majority did not offer their services to the

army during the war; thus of all the holders of the registrar's appointment at Calcutta Eye Infirmary only one came forward to join the army. Although the shortage of eye specialists was not acutely felt during this period as regards quantity, yet the quality left much to be desired. Two weak spots were noticed, viz., operative surgery and teaching. It should, however, be placed on record that several of those older Indian ophthalmologists, who applied for commissions during this period, proved most useful officers and rendered valuable service in positions of considerable responsibility. Among the younger men also there were not a few whose keenness both to acquire further knowledge of their speciality and discharge their military duties with efficiency went far to compensate for their initial lack of experience. There is no doubt that India possesses a number of men who, if given sufficient opportunity for proper training, would certainly become excellent military ophthalmic specialists.

TRAINING

Specialists : The possibilities of training medical officers in ophthalmology, with a view to classifying them as graded specialists, were limited by the scarcity of suitable trainers. During 1942-43, India was denuded of RAMC specialists; of the nine left five only had qualified in the United Kingdom, (the rest being of Indian or Central European origin) and only four of these had any considerable experience in, or capacity for, teaching. The number of centres at which trainees could be dealt with was, therefore, severely restricted.

Of those who applied for training in ophthalmology comparatively few possessed that background in the subject which is essential for anyone practising as a specialist, but of a large number of candidates 17 IAMC and 3 RAMC trainees were after the necessary attachment classified as graded specialists; 16 IAMC and 2 RAMC officers were not found suitable and were returned to general duty.

Nursing Officers : A fair number of Queen Alexandra's Imperial Military Nursing Service sisters with experience in ophthalmic nursing were available in India and it was not considered necessary to run courses in ophthalmic nursing as was done with benefit elsewhere. Apart from the larger base hospitals, the great majority of in-patients were among local Indian troops in combined or Indian military hospitals where either establishment or accommodation did not permit of attachment of British sisters. On the other hand there was grave shortage of Indian Military Nursing Service sisters and Auxiliary Nursing Service cadets, and although establishment allowed for an ophthalmic sister in every hospital with an eye centre, considerable difficulty was encountered in obtaining sisters even for the larger eye departments in IMHs. It should be mentioned here that, through the very willing co-operation of the principal matron at GHQ, with very few exceptions the services of all sisters in the whole command who had obtained a certificate in ophthalmic nursing or undergone training at any large eye hospital in the United Kingdom were placed at the disposal

of consultant ophthalmologist and posted according to his recommendations to take charge of the eye wards in those British or combined hospitals where the volume of such work was sufficient to justify this step. The beneficial results of this procedure as regards nursing of eye cases in these hospitals would be difficult to overestimate.

Orderlies : In all eye centres and units in India it was essential to arrange for carrying out the routine treatment of the external diseases of the eye. The specialist was responsible for those arrangements but he did not have the time to carry out the treatment personally for every case under his care. It was his duty to train a subordinate to do so. Due to shortage of Indian sisters, efforts were made to train and employ orderlies. To avoid the disorganisation due to frequent postings and to obtain personnel of the right type, approval was obtained for the upgrading of these orderlies (except in BGH on War Office establishment) to sergeant or havildar. Establishment was also authorised for one such ophthalmic orderly in each eye centre (Indian or British according to the establishment of the parent hospital), and in each Indian ophthalmic unit. Special courses of instruction for ophthalmic orderlies were instituted at the eye centre at Poona. Each course lasted four weeks and included lectures and demonstrations by the specialist, the ophthalmic sister, the optician, a trained ophthalmic orderly and an officer in charge of stores. An examination was held at the conclusion of each course. The first course started on 27 November 1944. The standard aimed at was high, though not unreasonably so. A large proportion of those detailed to attend the earlier courses were badly selected and failed to pass the final examination. Those candidates who did pass were invariably reported on later as being most useful and efficient. Owing to repatriation and release schemes, the supply of these men never equalled the demand, and to keep the field units up to strength the first seven courses had of necessity to be for British personnel. The provision, however, of trained Indian ophthalmic orderlies for routine work in the eye departments of garrison hospitals in India is regarded as being of considerable importance.

OPHTHALMIC EQUIPMENT

Owing to the rapid expansion of the medical services in 1942-43, there was a serious shortage of ophthalmic equipment, and a number of locally made operating instruments were obtained and issued to the newly formed centres and units. These were of inferior quality and workmanship, and were found to be more or less useless. There was also a shortage of ophthalmoscopes.

Between 1943 and 1945 the position steadily improved. All the indigenous instruments were withdrawn and replaced by articles of British manufacture, and by the summer of 1945, there were no deficiencies of the ordinary standard equipment in any ophthalmic installation in the India Command or the SEAC.

A great difficulty was encountered in the provision of items of special equipment—slit-lamps, magnets, and diathermy apparatus.

It was the deficiency of the latter two which necessitated the evacuation of all casualties with intraocular foreign bodies to Calcutta up to the middle of 1944. Owing to a series of errors and delays, the first ophthalmic diathermy apparatus was not made available for a military hospital in the India Command or the SEAC until a year later. The position regarding slit-lamps was less acute, as these instruments began to arrive in India in 1944. Indents for all these items were submitted from India to the United Kingdom in 1943. No doubt India came late into the field in this matter, but in view of the extent to which the War Office was able to make corresponding provision for units under their control in 1944-45, the lack of an effective central co-ordinating authority in the United Kingdom as regards priority of supplies was certainly severely felt in India. The same applied to maintenance supplies of spectacles.

During 1943, all ophthalmic stores and equipment (with the exception of a few items in common use such as eye shades and droppers) were concentrated in the Army Medical Stores, Bombay, a step which facilitated their inspection, control and distribution.

During 1945, in connection with formation in India of a base for ALFSEA, opportunity was taken to revise the PVMS (07 Section) in order to bring it into closer correspondence with the War Office *Price List of Medical Equipment* (PLME). At the same time MME scales of Indian ophthalmic units and centres were completely revised with the same object.

SPECTACLES

Before the war, the supply of spectacles to army personnel in India did not apparently present difficulties. The number of British troops needing them was small; for Indian troops no issue was authorised. The spectacles were obtained by contract from local opticians. With the sanction (temporarily, as a war time measure) for provision of one pair to Indian troops, and the arrival of fresh British forces, the existing system for provision of spectacles broke down. The delays inherent in the method of payment of civilian contractors caused the latter to hold up deliveries until their outstanding bills were settled. In the autumn of 1943 partly due to shortage of supplies one contractor in Bengal had over 2,000 jobs outstanding. The system of supply by army spectacle centres, which had already been adopted in every other theatre of war including Persia and Iraq, was instituted. The first installations under the new establishment (of a principal spectacle centre and seven subsidiary centres) began functioning in April 1944. During 1944 (April to December) and 1945 (January to June), these centres completed 16,145 and 16,614 jobs respectively.

In July 1945, the spectacle organisation in India and South East Asia was still restricted to the original establishment far below the proportion which existed in British Liberation Army and Central Mediterranean Force. The efficiency of the scheme was limited by the small number of centres authorised and the shortage first

of edging stones and later of optical maintenance supplies. The reason for this was the same as that for shortage of certain items of special ophthalmic equipment. With the great distances in India a service dependent on postal arrangements is bound to be a slow one. There is, however, no question that the method, whereby the army supplies its own spectacles, is the only practicable one in any theatre of war.

The British Army Form 1-1240 (modified for India) was introduced in place of the old Indian Army Form M-4 to the considerable satisfaction of all concerned.

The provision of spectacles from army sources necessitated the institution of a new section (No. 28) of PVMS comprising spectacle components (i.e., frames in a variety of standard sizes and lenses of a wide range of powers) and the equipment required for spectacle production at army spectacle centres.

ARTIFICIAL EYES

The supply of artificial eyes was somewhat of a problem in the earlier years of the war, as the total stocks in medical stores were not large. It was necessary to have a wide selection at all stations where personnel were sent for fitting a satisfactory prosthesis. For a considerable period the stocks were concentrated at Poona, but in 1945, six opticians were obtained from the United Kingdom who had undergone a course of instruction in making artificial eyes from plastic materials. The supplies from overseas also increased. It was then possible to fit and issue artificial eyes from seven widely dispersed centres in India.

ACCOMMODATION

The location of eye departments at many garrison hospitals in India, as well as the creation of centres in the large IBGHs, raised problems of accommodation, the solution of which varied in almost every single military station. In a few, the old eye department at the Indian or British military hospital, generally in cramped and ill designed quarters, remained in use. In others, new buildings were erected or existing buildings were adapted for the purpose. Unfortunately, in the earlier days of the war, the designing of these departments was undertaken by individuals who were not familiar with the latest ideas on the subject. The result was a small and ill ventilated dark-room, largely occupied by a big light-baffle and a consulting room in which the correct distance from patient to test-type was difficult to obtain and retinoscopy was not possible owing to ill planned lighting. Much patience and considerable expenditure were required to put things right. A more modern design was not adopted as a standard till 1944. The eye department accommodation was reconstructed or remodelled in no less than 23 stations in India, excluding base hospitals. As a result, India possessed some excellent military ophthalmic departments, notably

that at the main eye centre at Secunderabad which was described by a competent independent authority as the finest British Army ophthalmic department in the world.

VISUAL STANDARDS

Prior to 1944, the visual standards for officers of the Indian Army were in conformity with the regulations for admission to the Indian Military Academy, Dehra Dun. For IORs, the old Dot Test Card (Indian Army Form M-1219) was still in force, the examinee being required to count the dots at ten feet for categories A and B (see to shoot and drive) and at five feet for category C (see for ordinary purposes). In *Recruiting Regulations for India* there were also provisions regarding the exclusion of recruits with certain types of trachoma and the admission of men of 'inferior grades' (e.g., sweepers) with defective vision. The visual standards laid down by the War Office were applied to British troops in India as elsewhere. The standards for officers were considered to be somewhat high for general application to officers in war time, and a new scale was drawn up and approved in 1944.

As regards Indian troops, the visual acuity required with the Dot Test Card was relatively low, even the higher standard being slightly less than 6/24 in each eye. That test, which is rough and unscientific, had been in force for many years and on the whole had not proved unsatisfactory. It is simple and can easily be carried out where illiterate troops are concerned. But the adoption of the White Paper concerning entitlement to disability pensions and its attendant implications necessitated a re-examination of the whole subject, since it was essential that ophthalmologists should be able to make an accurate record of their patients' visual acuity, and this implied the use, almost universally adopted, of test-types constructed on the Snellen principle and read at a distance of six metres. Consequently a fresh scale of visual standards, in close conformity with British scales, was drawn up and adopted in 1945. For illiterate troops the '*E*' test, also on the Snellen principle, was made available, and the use of test-types in Hindi and Urdu scripts (which were quite unscientific) was discontinued. The importance of having a proper record of visual acuity of a recruit on entry is obvious, since it is against this record that attributability to service of any subsequent visual deterioration must be assessed.

MEMORANDUM ON OPHTHALMOLOGY

Owing to the ever increasing number of regulations and instructions issued during the war which had bearing on the work of army ophthalmologists serving in India, a pamphlet was issued early in 1944 to every ophthalmic specialist in the command in which were embodied all the current instructions relative to his particular branch of army medicine. These dealt, amongst others, with such matters as visual standards, medical categorisation, disposal of one-eyed personnel, assessment of disability, provision of spectacles and artificial eyes, use of sulphonamides, and the treatment of burns, cases of intra-ocular foreign bodies, and casualties due to chemical warfare.

Stocks of this memorandum (*Medical Directorate, India, Technical Instruction No.* 20) were exhausted, and a complete revision was almost ready for the press when hostilities ceased. British and American Journals of Ophthalmology, and Archives of Ophthalmology, all published monthly, were received at the GHQ and circulated by post to the ophthalmologists in the India Command.

MONTHLY REPORT—OPHTHALMIC

In every grade and branch of army work there never cease to be complaints against the imposition of filling in army forms and returns. Nevertheless, the institution of the monthly ophthalmic report, rendered in duplicate, one copy direct to Medical Directorate at the GHQ and the second through the usual channels, proved of great value in enabling the Medical Directorate to keep closely in touch with certain important details of each specialist's work, in particular the number of new cases examined, or spectacles ordered, or operations performed, and also of invalidings and of down-gradings of medical categories. These returns, therefore, provided a basis for future planning of location of eye centres and also enabled a very accurate forecast to be made of the spectacle centre requirements throughout the India Command.

INDEX CARDS—OPHTHALMIC (IAFM-1273)

A card-index system was introduced in 1944 to facilitate the keeping of records of patients' notes, and these cards were made available to all ophthalmic departments throughout the command.

VISIT OF CONSULTANT OPHTHALMOLOGIST, WAR OFFICE

Amongst other War Office consultants, who visited India in 1944-45, was Brigadier Sir Stewart Duke-Elder, consultant ophthalmologist, War Office. The programme arranged for him included visits to the ophthalmic departments at hospitals at Delhi, Bombay, Poona, Secunderabad, Bangalore and Calcutta, and also a tour in the South East Asia. He arrived at the beginning of March 1945, and returned to the United Kingdom at the end of the month. Tour notes subsequently issued by him drew attention to the need for the further development of the ophthalmic service in the ALFSEA.

RED CROSS SUPPLIES

After consultation with the Red Cross authorities six items of special ophthalmic dressings were standardised. Patterns were circulated to work parties throughout India, and the availability of these dressings notified to all ophthalmologists serving in the India Command.

ST. DUNSTAN'S

St. Dunstan's Hostel for war blinded men was opened in leased premises at No. 54, Rajpur Road, Dehra Dun, and received the first cases in July 1943. By July 1945, 107 admissions and 33 discharges had been notified. Four British cases were admitted in the earlier days for short periods while awaiting passages to the United Kingdom. When evacuation to the United Kingdom became easier, British cases were transferred there direct, usually by air, as soon as they were fit to travel.

The inmates at St. Dunstan's were all examined and treated by the ophthalmologist at No. 136 IBGH Dehra Dun. In the early stages a number of psychopathic cases had obtained admission and had to be transferred elsewhere ; admission was thereafter restricted to cases of genuine organic blindness.

Out of the 107 admissions, 53 were battle casualties or battle accidents (one dating from 1915), 13 more were accidents not connected with battle, and 41 were from medical causes (e.g., glaucoma).

The period of rehabilitation prior to discharge from the army was extended in 1945 from 4 to 18 months.

Of the 33 discharges, four British cases left for the United Kingdom, in 14 cases training was complete, in seven cases it was incomplete or failed, three cases were transferred for psychiatric treatment, and in five the sight improved sufficiently for the case to be able to leave the St. Dunstan's Hostel.[1]

CLINICAL

INDIAN TROOPS

Eye cases were relatively and absolutely far more frequent among Indians than British. External diseases (conjunctivitis and keratitis of various types) accounted for the great majority. Iritis was not uncommon, the usual cause being syphilis and except in severe old standing cases good results were obtained with standard antisyphilitic treatment.

The problem of trachoma among Indian troops is the problem of competent and conscientious examination of recruits. If the regulations were observed with reasonable care, the amount of hospitalisation and invaliding for trachoma and its effects would be vastly reduced. There is little evidence that trachoma is to any extent contracted primarily by Indian soldiers during service ; considerable numbers of troops were, however, constantly seen in eye departments with evidence of old trachoma of varying severity, commonly resulting in corneal scarring and a tendency to secondary conjunctival infection and relapses of ulcerative keratitis. Such cases came to hospital for treatment of a superimposed conjunctivitis. Almost all these men should have been rejected as recruits.

[1] See also volume on *Administration*, Appendix II, page 495.

Sporadic cases of retinitis pigmentosa have been observed, but except for a type of retinitis proliferans usually starting near the optic disc and not infrequently noted among younger men, fundus conditions were apparently less common in Indians than in British troops. There were two other conditions which occupied a disproportionate amount of ophthalmologists' time, viz., so-called night-blindness and self-inflicted conjunctivitis. Genuine cases of night-blindness were not common, but the usual scientific tests for this condition were inapplicable to the Indian soldier because they depended almost wholly on subjective factors. More reliable information was obtained from practical tests, such as whether or not a man can find his way to an outdoor latrine in the middle of a moonless night. It was of course necessary to examine soldiers reporting for night-blindness since a proportion of them were straightforward cases of defective vision, due generally to the opacity of the media and more rarely with evidence of vitamin deficiency. But it was also necessary to discourage men from reporting sick unjustifiably, and the standing instruction was that men complaining of night-blindness in which no organic cause was found should be recommended for extra training in night-duties.

Self-inflicted conjunctivitis, usually produced by inserting a vegetable irritant such as crushed jequirity or castor oil seed into the conjunctival sac, was a more troublesome matter.[2] In addition to disciplinary action, the standing instruction was that cases not needing specialised treatment were not to be admitted to hospital. Where through ignorance the practice was overdone, tragedies occurred, and two cases of bilateral total blindness from this cause were seen. As with night-blindness, the condition was liable, when not firmly handled, to assume epidemic proportions. The incidence of these cases gradually decreased.

One curious variety of self-inflicted conjunctivitis appeared for the first time in 1944, and cases were reported almost simultaneously among Indian troops in the North Western Army and West Africans in the Arakan. The ingredient was mepacrine, presumably intended to simulate jaundice, and it is of interest that among the earliest reported cases were several Africans who were, in fact, convalescent from infective hepatitis. The condition is not difficult to distinguish clinically from a genuine icterus, and in early cases the mepacrine can be detected chemically in the conjunctival fluid.

BRITISH TROOPS

The great majority of British cases seen at the eye departments were, as usual, sent for refraction ; the numbers attending were least in forward areas, greatest in and around a base. Cases of chronic blepharitis were not numerous, but there were one or two outbreaks of superficial punctate keratitis ; dendritic ulcers following a fever, usually malaria,

[2] In a series of 3,330 ophthalmological patients, 9·82 per cent. were found suffering from self-inflicted conjunctivitis. Of these 28·75 per cent. cases showed involvement of the left eye, 32·54 per cent. of the right eye and 37·00 per cent. of both eyes.

were common, and there were occasional cases of deep keratitis of an intractable type for which, after all investigations had proved abortive, the patient almost invariably had to be invalided to the United Kingdom. No definite case of proved trachoma among British troops was reported.

AFRICAN TROOPS

The prevalence of syphilis and yaws was largely responsible for the relatively high proportion of internal conditions among ophthalmic cases in African troops. Thus in one West African hospital out of 726 new cases examined, excluding refractions, during 12 months ending June 1945, the following were observed :— choroiditis—88, iritis—71, optic neuritis or atrophy—55 and cataract—23.

INVALIDING

Certain statistics are available showing the principal conditions for which British cases were accepted by the Standing Medical Review Board, Poona for invaliding to the United Kingdom. Similar data for the discharges in India of Indian cases on medical grounds are also given.

TABLE I

Invalidment (eye diseases)—Indian and British troops.

Diseases	Indian Troops		British Troops		
	1943	1944	1943 (May to December)	1944	1945 (January to July)
Diseases of lids	5	8	...	3	3
Diseases of lacrimal sac ...	13	13	...	...	...
Diseases of conjunctiva (excluding trachoma) ...	62	86	...	3	1
Trachoma	407	461	...	...	...
Diseases of cornea ...	304	318	...	7	8
Diseases of iris and ciliary body	38	44	1	8	3
Diseases of lens	139	134	2	8	4
Diseases of vitreous ...	...	1	1	2	...
Diseases of choroid ...	19	13	3	10	6
Diseases of retina	46	69	6	9	5
Diseases of optic nerve ...	18	34	3	4	5
Glaucoma	4	2	3	2	1
Panophthalmitis	2	3	...	1	...
Anophthalmos	8	12	...	10	6
Congenital conditions ...	6	...	...	1	...
Muscle-imbalance ...	4	3	1	2	...
Refractive errors	192	281	15	13	3
Unclassified	255	153	2	10	4

The following comments may be made.—

(a) The British manpower wastage on account of eye diseases was very low.

(b) The bulk of the invalidings for trachoma among Indian troops were for old established disease and its sequelae. These should be detectable on recruitment by medical officers. Within two years, 868 cases had to be invalided and of 622 cases of keratitis the majority were certainly due to trachoma.

(c) As regards the refractive errors, there was on occasions some misunderstanding and misinterpretation of rules for medical categories, and a number of cases may have been invalided for visual acuity who could see well enough for their work.

(d) The high figure for unclassified cases was due to failure on part of presidents of medical boards to refuse such vague diagnosis as 'defective vision'. The gradual training of army ophthalmologists would, it is thought, reduce this figure to negligible size.

SULPHONAMIDES AND ANTIBIOTICS

Experience in India as regards the use of sulpha drugs in ophthalmology did not differ notably in any way from that in other theatres of war. Sulphacetamide was available as an ordinary medical supply during the last years of the war, and was supplemented with other sulphonamides such as M and B 760 administered internally where indicated. The extent to which these drugs were used depended on the clinical judgement of individual ophthalmologists ; there was no doubt that local administration of sulphacetamide drops was of considerable value in clearing up the great majority of cases of simple conjunctivitis and in controlling secondary infections in established trachoma, especially in stage III.

Penicillin was not issued in any quantity to army medical units in India before 1944. A supply of lamellae was made available to all important ophthalmic departments towards the end of that year ; the results reported were variable, certain specialists observed distinct improvement, while others noted that the application of the lamellae was attended with marked irritation and discomfort. The use of penicillin as drops only became general during the final months of the war.

BATTLE CASUALTIES

Until the beginning of 1944, there were no adequate arrangements for dealing with casualties having penetrating eye injuries with intraocular foreign bodies, except by transferring them to Calcutta and using the facilities at the Eye Infirmary there (by courtesy of the Professor of Ophthalmology, Lieut.-Colonel E. W. O'G. Kirwan, CIE, IMS, and later Captain E. J. Somerset, IMS). The lack of the specialised equipment for dealing with such cases, i.e., electromagnets and diathermy apparatus, has been referred to above. It was not possible to instal a

magnet even in the advanced base hospital (No. 14 BGH) at Comilla until well on in 1944, and no ophthalmic diathermy machine was available until 1945. The instructions regarding serious eye injuries were that they were to be transferred to Calcutta by air at the earliest opportunity. In spite of difficulties connected with the nature of the fighting (especially in the early part of 1944) and the monsoon, the majority of these cases were, in fact, got back to Calcutta without any unavoidable delay, and during the Imphal and Kohima fighting many of these patients were in bed in the Calcutta hospital within three days of being wounded.

There is no doubt that where all the necessary facilities, i.e., experienced ophthalmic surgeons, adequate equipment (with diathermy, electromagnet and reliable current), proper theatre facilities, skilled nursing and the required bed accommodation are available in forward areas, the sooner a magnetic intraocular foreign body is extracted from an eye the better. Until the last year of the war it may be said that, excepting in some instances the nursing requirements, none of these facilities were to be had, and the choice lay between attempting this work under inadequate conditions forward, or following the policy advocated in *Section XXII of Field Surgery Pocket Book* (*War Office*, 1944), and getting cases back to the base as early as possible. At the same time, the locations of the ophthalmic units in ALFSEA were so planned as to make examination and treatment (including emergency operations such as excision of prolapsed uveal tissue) available at all points where casualties were likely to be staged on lines of communication. The eye department of the advanced base hospital at Comilla, from the middle of 1944 onwards, did excellent work under none too easy conditions.

Although in the light of the final clinical results of the earlier series of cases, the wisdom of this policy has been questioned, the opinion was generally held by all who were familiar with the actual conditions that no alternative was practicable at any rate up to the end of 1944, after which the responsibility for advice in the matter of policy ceased to be that of the consultant ophthalmologist, India Command.

With the exception of some Indian patients who were sent to Lucknow, and a small number who arrived by hospital ship at Madras, almost all eye cases arriving in India from the eastern theatre until the close of hostilities were treated at Calcutta and subsequently, unless fit for duty, were evacuated by train to Secunderabad. The statistics given below are of the eye patients seen at the latter station, and include all the worst cases but exclude all those who were discharged fit at any hospital further forward. Numbers of the latter are probably not large, but in consequence the actual figures show less good results than would be representative for all ophthalmic casualties.

The details given below are from a series of battle casualties or battle accidents received in 137 IBGH(IT), Secunderabad, and reported on by Lieut.-Colonel L. B. Somerville-Large, adviser in ophthalmology, Southern Army.

Unilateral injuries	321
Bilateral injuries	61
Head wounds affecting vision	15
Total	397 (i.e., 443 eyes)

Serious wounds	408
Minor wounds	35
Total	443

Serious wounds

Useful eyes	89 (22 per cent.).
Lost eyes (i.e., vision less than 6/60) ...	319 (78 per cent.).
Total	408

Head wound cases.

Useful eyes	17 (56 per cent.).
Intraocular foreign body cases	92 (20·77 per cent. of 443 eyes).
Number of cases where foreign body removed...	40
Useful eyes	20 (21·7 per cent.).

Blindness.

Head wound cases	4
Ocular injuries	22 (5·44 per cent. of 404 cases).
Total	26 (6·44 per cent. of 404 cases).

Missiles.

Grenade	214 (63·51 per cent.).
Shell	47
Bullet (machinegun and rifle)	41
Booby trap	14
Land mine	9
Mortar	8
Bayonet	2
Burns	2

All eye cases coming to this centre are shown in the series, including those in which the original injury destroyed the eye and enucleation (or evisceration) was undertaken in forward areas. In the great majority of penetrating injuries where the eye was ultimately lost, gross vitreous haemorrhage supervened and the globe eventually shrank. It is not possible to state with accuracy whether the haemorrhage occurred at the time of injury or subsequently (e.g., during evacuation), but in a series of 29 cases of intraocular foreign body referred to Eye Infirmary, Calcutta for magnet, the vitreous was clear in three, already opaque in 15 and not seen (cataract) in 11.

Whatever the corresponding figures may be for intraocular foreign bodies dealt with in other theatres of war, the figures quoted above were disappointing. Two factors are of importance here, viz., interval before the foreign body was removed, and the nature of the injury itself. In a Secunderabad series, out of 42 cases where removal was effected or attempted the time of operation was as follows :—

2nd to 13th day	...	...	...	11 cases.
14th to 27th day	...	...	...	9 ,,
28th to 42nd day	...	...	...	9 ,,
2 to 6 months	...	...	...	13 ,,

In the Middle East series of cases reported by Major Stallard, the time factor is not represented as being of paramount importance. For practical purposes the significant detail is not the interval before the operation was performed but before it could have been performed. It is only fair to remember that accurate localisation and the deliberate approach to the operation which produced the high ratio of successful cases in Major Stallard's hands were quite unobtainable at an Indian CCS or a forward IGH working in Assam, Burma or eastern Bengal in the conditions met with in 1943-44. The second factor is the type of injury, for it is of significance that out of 300 injured eyes 191 (63·67 per cent.) were from grenades and in the majority, in fact, the missile exploded within three yards. The proportion of magnetic to non-magnetic foreign bodies cannot be stated with accuracy but was certainly as high if not higher than in other theatres of war.

DEFICIENCY DISEASES

The adviser in ophthalmology, Southern Army, submitted a report on a series of nine cases of Indian and 34 British POW repatriated from Rangoon in the summer of 1945, and examined four weeks after release. The report was not as full as it might have been, because these men only remained for a brief period in the area before onward transit to the United Kingdom.

Eight of the Indian cases showed advanced stages of trachoma and their eyes were in a very irritable condition ; one of them was almost blind. In two cases there was pallor of the optic disc with loss of vision. The ninth case had had one eye removed on account of shell wound and the vision of the other eye was much reduced on account of retro-bulbar neuritis. There is no doubt that the trachoma cases suffered considerably from lack of treatment while in captivity.

Of the British cases, 12 complained of loss of vision. The onset of the symptoms varied between 2 and 15 months from date of being captured. The average length of imprisonment of this series was two years and seven months. In all but one of these men the optic discs showed pallor without any arterial constriction ; in addition, three other men with pallor of the disc had normal vision. A number of men also stated that while in captivity they suffered from night-blindness which was a common complaint among the prisoners. They recovered

rapidly (within at the most four weeks) from the latter symptom, but the loss of visual acuity remained.

ROLE AND LOCATION OF OPHTHALMIC UNITS IN WAR

Experience gained during World War II has indicated certain principles in planning ophthalmic services for an army in the field which with obvious modifications depending on air transport, the type of terrain and the weapons used, are likely to hold good for sometime to come.

ROLE

Stated briefly, the role is to render prompt and efficient ophthalmic treatment for all those requiring it, with reasonable economy in the provision of specialist personnel and equipment.

The staff, equipment and treatment at ophthalmic units varied with the unit to which they were attached.

Forward Units : These should consist of a specialist and a trained ophthalmic orderly, with equipment according to the scale laid down by the War Office for British mobile ophthalmic units. This outfit is both comprehensive and portable, since it contains the instruments required for the performance of all usual diagnostic and operative procedures, packed in a manner which enables the outfit to be loaded easily on any form of mechanical transport available for field hospitals or CCSs. In this way, ophthalmic cover can be provided either for forward areas in zones of active operations or alternatively for isolated forces such as those despatched to various widely separated localities in South East Asia during and immediately after the close of hostilities in 1945.

The types of cases handled by these forward units are (a) battle casualties and accidents in the earlier stages, (b) cases of ophthalmic disease (usually of minor severity among hardened troops in the field) and (c) refractions. The last named, though apparently unimportant, are often a cause of considerable temporary wastage of manpower in the field. Local considerations nearly always limit severely the bed accommodation available in the parent unit to which the ophthalmic unit is attached, and only those who cannot be moved or will be discharged fit within a few days can be retained in forward operational areas.

Line of Communication Units : (a) *Staging Points.* The personnel and equipment should be as for forward units. The ophthalmic work comprises the routine work in the area, and the examination and treatment of eye cases which are evacuated from forward areas.

(b) *Forward Base Hospitals :* Ophthalmic units located here have a very responsible function, since in addition to the routine work for local troops the specialist has to decide, according to the severity of the condition and the bed accommodation available, which cases to retain

and which to evacuate to the base. In addition to full equipment, an ophthalmic sister should be available here, and since the work is apt to be heavy at times, a junior specialist or trainee may with advantage be attached to the ophthalmic unit. The specialist officer-in-charge should be a good surgeon and of sound clinical judgement.

Base Hospitals : The personnel should be as for an ophthalmic unit at a forward base hospital, with one or more additional specially trained sisters according to the number of beds and the amount of operating undertaken. Apart from the care of local ophthalmic sick and a considerable amount of medical board work, the type of cases from forward areas depend largely on the smoothness and rapidity of the evacuation of convoys along lines of communication. Since long term cases are apt to accumulate here, ample provision of bed accommodation is essential. Other specialised units such as neuro-surgical, maxillo-facial and psychiatric are attached to base hospitals, and the ophthalmologist's services will be required in dealing with a proportion of the cases under the care of these units.

Garrison Hospitals : The work of an ophthalmologist in garrison hospitals does not differ markedly in war from what normally obtains in peace time except that the concentration of troops in the areas surrounding such localities is likely to be much increased, and a good proportion of his time will be occupied in travelling to outlying stations. The equipment for refraction and the simpler therapeutic measures should, therefore, be easily packed and portable. Especially at isolated stations, an ophthalmologist must be prepared to undertake almost any form of major ophthalmic operative work.

LOCATION

The efficient planning of ophthalmic cover for troops on active service necessitates close co-operation with the operational division of the General Staff. The data required are :—

(i) Location of all base, general and field hospitals and any special roles allotted to each.

(ii) Approximate concentration of troops in each area.

(iii) Policy regarding evacuation of casualties along lines of communication and, in particular, facilities for air transport.

Based on above knowledge, the following principles guiding the location of ophthalmic units became established as a result of experience in the recent war. In all cases each unit must be attached to some other medical formation both for administrative purpose and also to obtain bed accommodation for those eye cases who cannot be treated as out-patients.

Forward Units : These should be attached either to field hospitals or CCSs which are so located as to drain reasonably large areas through the existing lines of communication. If the specialist is too far forward

he does not do a full day's work, if too far back he does not assist in conserving manpower in fighting units by preventing evacuation of trivial cases.

Line of Communication Units (*a*) *Staging Points :* An ophthalmic unit is required here only when convoys of sick cases are normally staged here or when distances between neighbouring ophthalmic units are so great that even trivial cases may become severe through lack of specialised attention for protracted periods. The more rapid and efficient the transport arrangements, the fewer eye units are required at staging points.

(*b*) *Advanced Base Hospitals :* Wherever these units are located, an ophthalmic unit is essential.

Base Hospitals : Every such hospital, or group of hospitals, will have an ophthalmic unit. Apart from other considerations, the unit should be attached to the same hospital at which the neurosurgical and/or maxillo-facial units are located.

Garrison Hospitals : Only when a sub-continent such as India is involved in war does the ophthalmic layout in garrison areas require special consideration. Relatively vast areas, containing bodies of troops varying from time to time in size from a NCO with a few men at some isolated post to one or more divisions have to be served by perhaps a single ophthalmologist. It is, therefore, inevitable that some eye cases may have to travel considerable distances to obtain specialist advice, or the specialist may have to spend a high proportion of his time in travelling to outlying stations. The location of ophthalmic units in garrison areas must, therefore, be determined in every instance by the local possibilities and requirements. Attempt was made during the war to locate the unit when possible, at one of the larger hospitals in a station near the centre of the area served, but from which communications were reasonably easy to all sub-stations which the specialist was called upon to visit. The work was further facilitated during the last few months of the war by the provision of equipment in a form, which was readily packed in an easily portable manner.

CHAPTER XXXIII

Orthopaedics

ADMINISTRATION AND ORGANISATION

Orthopaedic Centres : Prior to the middle of 1942, no orthopaedic centres, styled and organised as such existed in the Indian Army. The only orthopaedic centre for the armed forces was located in Bikaner and was equipped and staffed by the state. Almost all orthopaedic cases, therefore, were treated by general surgeons and most of the orthopaedic work was limited to setting up of fractures. The rapid increase of surgical casualties during the war made the provision of orthopaedic centres imperative. On 1 July 1942, two provisional centres (including an electrotherapeutic centre) to deal with 100 patients in each were started at No. 1 IBGH(BT) and No. 6 IBGH(IT) in Karachi. Of the 100 beds at No. 1 IBGH(BT) ten beds were assigned for officers. Essential equipment, additional to that authorised, was provided by the GHQ to the extent it was available and the following personnel were posted to each of the hospitals : one orthopaedic surgeon, two specially trained nursing officers, two qualified masseurs and two orderlies capable of being trained in plaster work. These two centres were soon increased to four by the formation of a further two centres at Nos. 2 and 3 IBGHs at Kirkee and Poona respectively.

A couple of months experience at these centres revealed the inadequacy of the existing make-shift arrangements. It was obvious that special arrangements for orthopaedic treatment in base general hospitals must be made without further delay. It was appreciated that orthopaedic casualties require not only special treatment but also rehabilitation and prolonged supervision. The treatment was required for many years in certain cases. The first great step towards setting up orthopaedics on its feet was the acceptance of the principle of treating cases right upto the final stage of rehabilitation. A properly organised scheme was, therefore, planned by Brigadier Grant Massie the consultant surgeon at GHQ. This scheme incorporated a number of orthopaedic, physiotherapy and rehabilitation centres. The discussions with financial authorities and other branches concerned lasted for over four months and finally on 24 January 1943, sanction was received for the formation, as a temporary measure, of seven orthopaedic units at the following hospitals :—

Hospitals	Beds
No. 1 IBGH(BT), Karachi	200
No. 6 IBGH(IT), Karachi	500
No. 3 IBGH(BT), Poona	500
No. 7 IBGH(IT), Kirkee	300
No. 130 IBGH(IT), Lucknow	700
No. 128 IBGH(BT), Secunderabad ...	1,000
No. 14 BGH, Bareilly	100

Later a full fledged orthopaedic hospital No. 146 IBGH was started at Jalahali near Bangalore. However, it was not developed fully as the war suddenly came to an end.

The beds allocated to these units were found from within the existing bed strengths of each hospital. The orthopaedic centres, however, functioned as detachable sub-units with their own staff and equipment. The units were completed as and when personnel and equipment became available. An orthopaedic unit consisted of surgical, X-ray and physiotherapeutic and occupational therapy departments. Each centre was, therefore, authorised a separate operating theatre, a plaster and anaesthetic room, a gymnasium, an occupational therapy room, an electro-therapeutic room and such covered ways between component parts of the unit as necessary.[1]

Early in 1944, about the time the rehabilitation centre attached to No. 7 IBGH(IT), Kirkee started functioning, it was decided to create a peripheral nerve injury centre. Gradually all the peripheral injury cases were concentrated in this hospital. A considerable part of the work there was orthopaedic not only because of the associated lesions but also because of failures of nerve regeneration requiring mostly orthopaedic treatment to equip the patients for civilian life, in the way of fixation of joints and tendon transplantation etc.[2]

The development of No. 7 IBGH(IT) into an orthopaedic hospital was completed to bring all amputee cases to this hospital and to shift the artificial limb centre of the army from Sialkot to Kirkee. Due to difficulties of transport a large number of cases had accumulated all over the country. As they slowly trickled in, their number increased to over 300 and for the following two years despite all efforts, the number of amputees was never below 200. It may be added that by 1944, facilities for treatment of orthopaedic cases in the Eastern Army were provided by No. 76 IGH, No. 63 IGH, No. 138 IBGH and IMH Alipore for Indian troops, by No. 47 BGH and No. 69 IGH(C) for British troops and No. 46 West African General Hospital for African other ranks. Arrangements for physiotherapy and rehabilitation were provided at Nos. 47 BGH and No. 69 IGH(C) for British troops and No. 75 IGH and No. 138 IBGH for Indian troops. In January 1945, an advanced fracture centre for British troops was opened in No. 17 BGH, Dacca. Orthopaedic surgery, however, was not available in ALFSEA before 1945. The cases from the Fourteenth Army area arriving at Calcutta were sent to Secunderabad and those arriving at Sirajganj were sent to hospitals in the Central Command. The time lag in getting these casualties to centres in India did not allow their early treatment.

PHYSIOTHERAPY

Building and equipping physiotherapy centres in each of the orthopaedic hospitals was not so great a problem as finding the staff

[1] For war establishment see Appendix A.
[2] For peripheral nerve injury centres see page 726.

to run them. The physiotherapists for service in India were mainly recruited by the War Office and the India Office in the United Kingdom. During the emergency a total of 20 physiotherapists were appointed in different hospitals in India.

At the commencement of the war a movement was afoot in the Chartered Society of Physiotherapists to establish a physiotherapy service, with commissioned ranks similar to the nursing services. However, commissioned status was not given to civilian physiotherapists in India. Awkward situations, therefore, sometime arose in dealing with orderlies. Established members of this class, who were posted to permanent peace time units, however, did not encounter any such difficulties. The pay of civilian physiotherapists was low as compared to Indian standards. Their travelling allowance was less than that admissible to the members of the nursing service. They were not granted any war gratuity or release leave, Japanese campaign pay, dearness allowance or antimalaria clothing or outfit. Their services could be terminated by one month's notice.

Two rehabilitation centres deserve special mention. One at No. 7 IBGH(IT) had a well equipped gymnasium, where over 10,000 treatments were given per month. This centre was the largest in the Southern Command. On account of the high proportion of nerve injuries the electrical side was well maintained. A diversional therapy department was also run there. The difference between patients treated in other hospitals, where no physiotherapy treatment was given, and those treated in this centre was well marked. The second centre was at No. 130 IBGH(IT), Lucknow, where a physiotherapist trained in occupational therapy was also posted. Here at its peak nearly 9,000 treatments were given per month.

In view of the inability to get trained physiotherapists, IAMC nursing sepoys were given training in rehabilitation and physiotherapy. Whatever proportion of RAMC masseurs was available was for service with British troops. In June 1944, two teachers arrived from the United Kingdom. They along with a team of 11 senior physiotherapists took over the training of IOR masseurs. The team was later augmented by ten more physiotherapists. The training school was in the first instance located at Jalahali. Later, after consultation with Madras Government, the training was imparted at Madras General Hospital, where part of the well equipped Barnard Institute was given over to the training school. The first batch of trainees included four nurses and nine sepoys. The course was of three months' duration. The syllabus included anatomy, lectures on dissection, physiology, remedial exercises, electropathy and massage. Examination was held at the conclusion of the course. For the second and subsequent courses the school was shifted to No. 7 IBGH(IT), Kirkee. In all the centres where physiotherapists were working, IAMC nursing orderlies nominated for training at No. 7 IBGH(IT) were required to spend at least a fortnight in preliminary training. Unsuitable candidates were returned to the unit and the others were sent direct to Kirkee. For the second course at Kirkee there were 53

candidates, one-third of whom were returned to units, as they did not conform to the requisite educational standard, viz., 3rd class English and 2nd class nursing. Only 50 per cent. of this number qualified after the course. In all seven courses of training were held, one in Madras, four in Kirkee and two in Secunderabad where a second school was opened in August 1945, and 115 sepoys, five civil nurses and one member of WAC(I) were trained. Short courses of eight weeks were also arranged for those who had undergone physical training courses at the Army Schools of Physical Training, Ambala and Kasauli, at Nos. 6, 7, 130, and 135 IBGHs at Karachi, Kirkee, Lucknow and Bareilly respectively. These men were trained for employment in convalescent depots. Lectures in physiotherapy followed by clinical demonstrations on electrotherapy, remedial gymnastics, physical training and massage were also given to medical officers under training at the Army Medical Training Centre.

An adviser in physiotherapy to the DMS in India was sanctioned in January 1945, and Miss M. R. Wheeler, the chief instructor of IAMC masseur training school was appointed to this post. The post was incidental to her normal training duties, and involved the touring of the whole of India in her spare time reporting on rehabilitation centres and depots, and advising on posting of physiotherapists and the trained IAMC masseurs. After the cessation of hostilities, the adviser was attached to Medical Directorate in her advisory capacity and assisted in the winding up of the war time physiotherapy service in India.

CLINICAL

Clinical problems that orthopaedic surgeons had to face were many. For want of necessary material it is not possible to review all the orthopaedic cases treated during the war. The results[3] of forward surgery in the Fourteenth Army from January to May 1945 in so far as these relate to fractures and joints and the following notes on the cases at No. 17 BGH, Dacca (Lieut.-Colonel H. I. Maister, RAMC), No. 74 IGH(C), Comilla (Lieut.-Colonel J. A. Baty, RAMC) and No. 7 IBGH(IT), Kirkee (Lieut.-Colonel H. R. Pasricha, IAMC), however, give some idea of the important observations made.

At No. 17 BGH and No. 74 IGH(C) each surgeon had a series of about 50 cases. All these cases were evacuated to India for their later treatment. At different times each surgeon adopted different methods of management. Their over-all figures show slight differences but detailed comparison shows that their results, by what appears to be the optimum method, were closely similar. Lieut.-Colonel J. A. Baty started by closing wounds early, soon after admission to hospital. One or two disasters occurred, quite probably due to inadequate forward surgery and he changed for a time to a technique of keeping the wound open for a week or more before closure. Finally he reverted to early closure (average seven days after wounding, two after admission) and achieved his best results

[3] See also Table I, Chapter XXXVII, page 755

TABLE I

Results of forward surgery—Fourteenth Army, January–May 1945 in so far as these relate to fractures and joints.

Region	Admissions	Deaths	Case fatality rate per cent.	Percentage survival
Fractures :				
Spine (paraplegia) ...	40	5	12·50	87·50
Spine (no paraplegia) ...	15	...	...	100·00
Femur	285	19	6·67	93·33
Leg	310	11	3·55	96·45
Foot	142	3	2·11	97·89
Humerus	287	5	1·74	98·26
Forearm	307	3	0·98	99·02
Hand and wrist ...	586	2	0·34	99·66
Joints :				
Hip	3	...	...	100·00
Knee	177	...	...	100·00
Ankle	41	1	2·44	97·56
Shoulder	51	1	1·96	98·04
Elbow	61	...	...	100·00

(75 per cent. complete success or partial success with site of fracture completely sealed off). Lieut.-Colonel H. I. Maister adopted early closure for the whole series (average thirteen days after wounding, two after admission) and achieved complete or partial success in 74 per cent. He later had a small series which he only closed partially. This method, designed for greater safety, was over this small series far less successful than those closed completely. Both surgeons used penicillin. Baty gave up local instillation of penicillin as dangerous in his environment and relied entirely on intramuscular injection. Maister used local instillation alone in 11 cases of which he gives no details; the remainder were treated with intramuscular injections combined, in severe cases, with local instillation. After early experience with posterior drainage through a large tube, a method which in his opinion led to infection, Baty discarded it in favour of a small temporary drain through the suture line. Maister used a similar small drain, or none at all. The following points emerge from their records :—

(a) The sooner after admission to hospital that the wound is completely closed the better, provided forward surgery has been sound.

(b) The length of time after wounding, between seven and fourteen days, does not affect the results.

(c) There is no evidence that local instillation of penicillin carries any advantage.

(d) Massive drainage by tube or incomplete suture is not to be recommended.

Other Fractures : Fractures of the tibia and fibula were often difficult to cover with skin by suture, and skin grafting had to be done, There was a tendency in the first enthusiasm to get wound closure and neglect the fracture until deformities were difficult or impossible to overcome. Both factors are important but good position of these bones is essential.

Compound fractures of the tarsus were as intractable here as on other fronts and many came to amputation.

Joints : Penetrating wounds of knee joints did extremely well with immobilisation and aspiration with or without instillation of penicillin, unless there was severe damage to the bones from a large retained foreign body. In simple cases the intra-synovial injection of penicillin was discouraged as carrying too much risk, in this theatre, of introducing gram negative bacilli.[4]

Originally at No. 7 IBGH(IT), Kirkee, the treatment of un-united fractures was attempted on classical lines ; cortical tibial grafts were employed to bridge the gap between the bone fragments.

This technique was found to suffer from several disadvantages, the most important being the time required for consolidation, usually, five to six months. The time was more than could be afforded as there was a big rush on beds on account of accumulation of cases. Also this prolonged immobilisation had its own drawbacks since it led to marked stiffness of joints and necessitated months of physiotherapy and rehabilitation for restoration of movement and function to the limb. In addition it was noticed that though the graft took, there was practically no new bone formation around it. This was another great disadvantage in the case of large bones like femur, tibia and humerus. Graft operations on these bones performed with this technique ended up with the two bone fragments joined by a narrow ledge of cortical bone. It soon became clear that a more satisfactory technique had to be found to suit the needs. A technique was required which would lead to early consolidation and produce enough new bone to fill up the gap between the large bone ends. It was concluded that cortical grafts did not possess enough osteogenic power and had to be supplemented.[5] As a trial cancellous bone removed from the ilium was tried along with cortical grafts. The results improved at once, more bone was formed and more quickly. It was, however, realised that operation was now more laborious and time consuming. To simplify matters an effort was made to find out if the cortical graft could be dispensed with altogether since it seemed to serve no purpose other than that of holding the bone ends together. In place of cortical graft the bone ends were secured with steel plates and screws and the gap between the fragments was filled with cancellous tissue as before. This yielded equally good results; the bone ends were firmly united within three months and enough new bone had formed to fill up the gap. This then became the standard technique and yielded very good results. Due to early consolidation,

[4] Report on Surgery in the Burma Campaign by Consultant Surgeon, ALFSEA, pp. 15-16.
[5] These are personal views.

the period of hospitalisation was cut short and the limbs did not end up with stiff joints and finally there was enough new bone formed to fill up the gap in large bones.[6]

Another great advantage of this technique lies in the fact that it did not lead to reduction in the length of the bone. On the contrary, any reduction of length due to loss of bone tissue on account of original injury could be compensated by deliberately fixing the fragments with a gap and filling it up with pieces of cancellous bone. This made it possible to deal with grossly mal-united fractures where otherwise a further reduction in the length of bone would have resulted.

A large accumulation of amputee cases was mainly due to local sepsis. In the pre-penicillin days, sepsis in war wounds was very common. In most cases either the original operation had been performed in the presence of sepsis or sepsis resulted long before they arrived at the hospital. The then practice and teaching was not to perform reamputations in the presence of sepsis and, therefore, treatment aimed at healing of all wounds before any attempt at reamputation. This was a very lengthy process. Arrival of penicillin provided the safeguard against sepsis and reamputations were attempted successfully even in the presence of large wounds under 'penicillin umbrella'. Practically in all such cases healing by first intention was obtained. Healthy stumps could thus be secured ready for limb fitting much earlier than before.

Other orthopaedic problems were un-recovered cases of nerve-suture. Foot-drop, for example, was a great handicap for Indian patients most of whom came from peasant class and wanted to return to the land. Foot-supports were provided but the patients were most unwilling to return to their villages with them. They argued that they could not be expected to do their job on the land with a foot-support. Some sort of permanent fixation method had to be employed. All such cases were operated upon and Lambrinudi's subastragaloid arthrodesis performed. Results of this operation were very satisfactory since the foot-drop was overcome without any interference with the ankle joint. Almost all patients were very happy at having had this operation performed.

There was also a fairly large number of unrecovered dorsal interosseus nerve lesions with wrist-drops. They were treated by the method of tendon-transplantation. The results of this operation were very satisfactory provided one of flexors of the wrist was left behind. If both flexors were sacrificed along with palmaris longus, the wrist lost its power of flexion and remained fixed in extension leaving the patient more disabled than before.

[6] For further details see Pasricha, H. R. (1948) *Ind. J. Surg.*, 10, 52.

APPENDIX A

War Establishment—Orthopaedic Wing

The following provisional war establishment was sanctioned for a unit of 100 beds, and extra personnel were authorised for each additional 200 beds. In assessing this establishment the following points were specially considered :—

(a) that orthopaedic treatment required not only skilled and continuous surgical care but also strictly supervised rehabilitation in order to produce good results; and

(b) that in view of the limitation of the manpower ceiling the establishment was the minimum feasible and compatible with requirements.

WAR ESTABLISHMENT ORTHOPAEDIC UNIT (100 beds)

Personnel

Detail	Number
Officers	
RAMC or IMS:	
Orthopaedic specialists (surgeons)	2
X-ray specialist	1
Rehabilitator	1
General duty	1
TOTAL	5
Nurses	
QAIMNS or IMNS:	
Theatre sister	1
Specially trained in plaster work	2
General duty	6
Auxiliary nursing service:	
Specially selected	6
TOTAL	15
Other ranks	
RAMC	
Corporal	1
Operating room attendants	3
Masseurs	3
General duty	5
Carpentry rehabilitator (a)	1
Handwork rehabilitator (a)	1
Physical training instructor (a)	1
Leather worker (a)	1
Splintmaker (a)	1
Bootmaker (a)	1
TOTAL	18

NOTE

Additional personnel are authorised as follows :—

Detail	Number
(i) *For each additional* 200 *beds.*	
Officers	
RAMC or IMS:	
Orthopaedic specialist (surgeon)	1
Rehabilitator	1
General duty	1
TOTAL	3
Nurses	
QAIMNS or IMNS:	
Sisters and nurses	4
Auxiliary Nursing Service:	
Specially selected	2
TOTAL	6
Other ranks	
RAMC:	
Masseur	1
Specially trained in plaster work	1
General duty	4
TOTAL	6
(ii) *For each additional* 300 *beds.*	
Physical training instructor	1
(iii) *For each* 400 *beds above* 600.	
Leather worker	1
Splintmaker	1
Bootmaker	1
TOTAL	3

Additional note.

(a) May be Indian Hospital Corps or civilians specially employed.

The above war establishment was found to be unworkable and was accordingly revised and the following new war establishment was sanctioned on 15 April 1943, which gave a large saving in British manpower, i.e., 9 (when used for British cases) and 4 (when used for Indian cases) as against the commitment of 23 in the first war establishment.

WAR ESTABLISHMENT

Indian orthopaedic wing

(For attachment to general hospitals for Indian or British troops which cater for orthopaedic cases).

Personnel

Detail	Number
Officers	
Surgical orthopaedic specialist (major)	1
Majors, captains or lieutenants (a)	3
TOTAL	4
Nurses	
Theatre sisters (b)	3
Auxiliary Nursing Service	6
TOTAL	9
British (c)	
RAMC:	
Sergeant (physical training instructor)	1
Rank and file	
RAMC:	
Privates (operating room attendants)	3
Private (instructor in handwork) (d)	1
TOTAL	4
Total British other ranks	5
Indian (e)	
Havildar	
IAMC:	
Physical training instructor(e)	1
Rank and file	
IAMC:	
Nursing Section :—	
Sepoys (operating room attendants) ...	3
Sepoy (instructor in handwork) (d) ...	1
Ambulance section, sepoys (batmen)	9
TOTAL	13
Total Indian other ranks	14

Detail	Number
Non-combatants (enrolled) (*d*)	
IAMC—general section:	
Carpenter and joiner, grade I	1
Blacksmith, grade I (splintmaker)	1
Saddler and harnessmaker, grade I	1
Bootmaker, grade I	1
TOTAL	4

NOTES

1. This war establishment caters for up to 200 orthopaedic cases and is additional to the normal war establishment of the general hospital to which it is attached.

The following additions will be made for hospitals with orthopaedic beds over 200 :—

For each additional 200 *beds.*	
Surgeon (orthopaedist)	1
For each additional 300 *beds.*	
Physical training instructor (Sergeant for British beds, Havildar for Indian beds)	1
For each additional 400 *beds over* 600.	
Blacksmith, grade I (splintmaker) ...	1
Saddler and harnessmaker, grade I	1
Bootmaker, grade I	1

2. When this wing is attached to a general hospital of any type, that hospital will be authorised to increase its establishment by 50 per cent. of the number of medical officers normally authorised for the number of beds in the orthopaedic wing, and by 100 per cent. of the remaining personnel authorised for the same number of beds.

ADDITIONAL NOTES

(a) One surgeon (orthopaedist)
One radiologist.
One officer trained in rehabilitation.

(b) Includes two specially trained in plaster technique.

(c) Will be provided in units catering for British orthopaedic cases only.

(d) May be replaced by specially employed civilians.

(e) Will be provided in units catering for Indian orthopaedic cases only.

In August 1943, the above war establishment was amended to make the position with regard to the nursing officers clear. The war establishment provided Auxiliary Nursing Service but they could not

be posted to hospitals for British troops. Accordingly on 10 August 1943, the establishment was amended to provide British service nursing officers for units catering for British troops and Auxiliary Nursing Service cadets for units catering for Indian troops.[1]

With regard to the inclusion of physical training instructors in the war establishment of an Indian orthopaedic wing, at the time the war establishment was originally drawn up, it was the opinion of the Medical Directorate that these instructors should be found from the medical services because their duties would chiefly be concerned with the rehabilitation of personnel who had suffered from disease or injury to bones and/or joints and a considerable amount of medical knowledge would be required to deal with such cases without danger of causing permanent deformity or undue delay in recovery, as might well happen if ordinary physical training methods were applied.

However, the posting of RAMC and IAMC personnel as physical training instructors did not prove entirely satisfactory. Although no permanent injury was reasonably anticipated from their efforts yet at the same time it was realised that these personnel did not possess the necessary background of physical training experience required to produce the best results, i.e., a combination of sound physical training experience plus the required medical knowledge.

A number of Army Physical Training Corps instructors had just then arrived from the United Kingdom and were being employed in convalescent depots. These instructors had received special training in the United Kingdom in 'Physical Medicine Remedial Exercises', but their number was likely to suffice the needs of orthopaedic wings for British troops only. It was considered that they would be more suitably employed in orthopaedic wings.

With regard to the IAMC physical training instructors for orthopaedic wings for Indian troops, the employment of better qualified extra regimentally employed physical training instructors was considered an improvement over any thing that could be found from the IAMC.

The provision of masseurs in orthopaedic wings at a scale of one per 100 beds was also considered necessary. These were to be employed in replacement of an equivalent number of nursing orderlies authorised on the establishment of the hospital to which the wing was attached. The rank of corporal was proposed for the RAMC masseurs and that of naik for IAMC masseurs.[2]

By then a great deal of confusion over the interpretation of this war establishment had come to light and the actual experience of its working over a period of one year had disclosed that certain amendments could be profitably carried out. Nursing officers could be provided at a sliding scale effecting a saving. A British warrant officer, class II in charge of rehabilitation could with advantage be employed and could do the work formerly done by an officer which was found to be an unnecessary British officer commitment.

[1] F. 2220/H(M).
[2] F/ 2220/ H (M).

A revised war establishment as under was accordingly sanctioned in May 1944.

INDIAN ORTHOPAEDIC WING

(Consisting of sections of 100 beds each for attachment to a hospital for Indian or British troops which cater for orthopaedic cases).

INDIAN WAR ESTABLISHMENT

Personnel

Detail	One section	Add for each additional section
Officers		
RAMC or IAMC:		
Surgical orthopaedic specialist (graded or recognised)	1(a)	1(n)
Major or captain (graded or recognised radiologist)	1	...
Captains or lieutenants	1	1
TOTAL	3	2
Nursing Officers		
Theatre sisters	2(b)	(c)(b)
Sisters (d)	3	(c)
TOTAL	5	(e)
British		
Warrant Officers		
RAMC:		
Warrant officer, class II (in-charge, rehabilitation)	1	...
Rank and file (f)		
RAMC:		
Corporal (operating room attendant) ...	1	...
Corporals (masseurs) (g) ...	1	1
Privates (operating room attendants) ...	1	(c)
TOTAL	3	1(e)

Detail	One section	Add for each additional section
INDIAN		
Rank and File		
IAMC:		
Nursing section (h):		
Naik (operating room attendant)	1	...
Naiks (masseurs) (g)	1	1
Sepoys (operating room attendants)	1	(c)
Ambulance section		
Sepoys (batmen)	5	1(c)
TOTAL	8	2(e)
Non-combatants (enrolled)		
IAMC—general section (i):		
Carpenter and joiner, grade I ...	1	...
Blacksmith, grade I (splintmaker) ...	1	(j)
Saddler and harnessmaker ...	1	(j)
Bootmaker	1	(j)
TOTAL	4	(k)
Attached		
British (f):		
Physical training instructor, Army Physical Training Corps (l)	1	(m)
Indian (h):		
Company havildar major instructor/havildar instructor, extra regimentally employed (l)	1	(m)
Civilian:		
Instructor in handwork	1	...

NOTES

Orthopaedic sections will be found from within the authorised bed strength of the hospital to which they are attached.

Personnel will be adjusted as follows :—

(i) Officers shown in this war establishment will replace an equal number of general duty officers or non-surgical specialists in the authorised war establishment for the parent hospital before inclusion of the orthopaedic beds.

(ii) Balance of personnel shown in this war establishment are additional to the authorised war establishment for the parent hospital as raised before the inclusion of the orthopaedic beds. (See also note (g) below).

ADDITIONAL NOTES

(a) Major.
(b) Includes or is one trained in plaster technique.
(c) One for each additional 300 beds.
(d) Will be British service sisters in British wing and Indian service in Indian wing.
(e) See note (c).
(f) For British orthopaedic wings.
(g) Will replace an equal number of RAMC/IAMC nursing orderlies in the parent hospital.
(h) For Indian orthopaedic wings.
(i) May be replaced by specially employed civilians.
(j) One additional at a total of 700 beds.
(k) See note (j).
(l) If non-medical trained physical training instructors are not available, they may be replaced by RAMC (British wing) or IAMC (Indian wing) personnel trained in physical training.
(m) One additional at a total of 400 beds and another at 800 beds.
(n) Major or captain.

CHAPTER XXXIV

Oto-rhino-laryngology

ADMINISTRATION

Before World War II, an establishment of four 'ear, nose and throat' (ENT) specialists was authorised in the India Command. The specialists were assigned to commands and most of their time was taken up with touring. In 1942, with the development of the India Command as a base for campaigns in Burma and South East Asia, special centres were created to cope with the altered situation. It was intended that ENT centres should be designed, equipped and staffed so that all types of ENT diseases could be treated. It was recognised from the start that such cases should as far as possible be concentrated in selected centres to economise in specialists, equipment and experienced nurses or orderlies.

Provision had to be made for convoy cases arriving from operational areas and local garrison sick. At first it was considered necessary to provide separately for these two classes. Later, however, the obvious advantages of centralisation were accepted. It was realised that most walking cases could be transported to centres for treatment and that specialists were then better able to carry out their work using static equipment. Thus ENT centres were started in garrison hospitals such as BMHs at Calcutta and Bombay, and in IBGHs such as No. 3 and No. 7 in Poona and Kirkee.

By the end of 1943, the following 21 centres were operating in India :—

Armies/Commands	Stations
North Western Army	Abbottabad Bannu Rawalpindi Quetta Karachi
Central Command	Lahore Lucknow Meerut Bareilly Dehra Dun Jubbulpore Delhi
Southern Army	Poona Kirkee Bombay Deolali Bangalore (later two centres one each in IMH and BMH). Secunderabad
Eastern Command	Calcutta Ranchi

The large BGHs had on their establishment an ENT specialist and held equipment according to the scale '1-1248'. West African units were in a similar position. There was no establishment for such specialists in IGHs.

In 1943, Indian surgical units (ENT) were formed. These were mobile field units with specialists and equipment, and could be attached at short notice to any IGH where the work was expected to be heavy. This plan proved extremely successful except that in some cases the specialist in charge of his unit failed to recognise that his activities must be under the direction of the commanding officer of the hospital. Occasionally specialists tended to take an independent line so that discipline suffered.

CONSULTANTS AND ADVISERS

Prior to 1942, there was no consultant or adviser in oto-rhino-laryngology to the India Command. Co-ordination of this service throughout the Indian Army was necessarily sketchy and unsatisfactory. During 1942, a consultant oto-rhino-laryngologist was appointed to the Southern Army and to his duties were added that of adviser to the GHQ. Based on Poona and attached to the Headquarters Southern Army, Bangalore, he was completely out of touch with the situation in Delhi. It was not until October 1944, that the Southern Army consultant was made consultant to the India Command. Shortly after this, four advisers were appointed, one each to Southern Army, Eastern Command, Central Command and North Western Army.

Appointment of advisers to commands and armies added tremendously to the efficiency of this service. These officers, who were promoted to the rank of lieut.-colonel, carried on clinical work, were called for consultation in difficult cases, and were responsible for teaching and reporting upon the capacity of trainees.

The consultant to the India Command personally knew almost all specialists, graded specialists and trainees. His recommendations for posting of personnel were, therefore, acted upon. The consultant also made recommendations concerning location of centres and units and largely controlled the issue of ENT equipment.

RELATIONSHIP WITH THE SEAC

The relationship of specialist units with the SEAC has been described clearly and concisely by the consultant ophthalmologist.[1] The thin ENT cover for forces in Eastern Bengal and Assam was increased gradually throughout 1944 by progressive attachment of surgical units (ENT) to existing IGHs and by the location of West African hospitals in Dacca and Cox's Bazaar.

In Ceylon, an ENT specialist of great experience on the staff of No. 35 BGH carried out almost all the ENT work. This was made

[1] See page 685.

possible by the posting of a graded specialist to No. 132 Ceylonese General Hospital, and by the fact that the Royal Navy Auxiliary Hospital had an ENT surgeon on its strength.

Late in 1944, the need for an adviser to the Eleventh Army Group was represented, and early in 1945, an adviser was appointed. From this time onwards the Consultant Oto-rhino-laryngologist, GHQ was not responsible for the Eleventh Army Group. Liaison between the consultant in India and the adviser in the Eleventh Army Group remained close upon all matters concerning equipment.

PERSONNEL

In 1942, there was a grave shortage of competent specialists and it became necessary to make good the deficiency by utilising a number of Indian specialists. Difficulty arose at once. The requisite number of Indian specialists was not readily available. The most able Indian specialists were firmly established doing essential civilian work and did not often volunteer for army.

Nonetheless, by the end of 1943, the specialist cover was adequate as regards numbers, but the general standard of work left much to be desired. The weak spot was operative surgery as became apparent much later ; cases which required operation had been left alone, whilst it was all too common to encounter bad operative results.

At the beginning of 1945, specialist in encouraging numbers had been drafted to India from the United Kingdom, a few experienced Indian surgeons had volunteered for service, and the training scheme was beginning to bear fruit. For the first time the ENT specialist cover was considered to be satisfactory. At this time a specialist pool was created and as a result, it was possible to post two officers to one centre if the work was too heavy for one.

In 1945, there were in the India Command and the SEAC 48 specialists as follows :—

Specialist pool	21
On strength of BGHs	7
Indian surgical unit (ENT)	15
West African general hospitals	4
East African general hospitals	1

TRAINING

Specialists : The facilities for training specialists were limited throughout the whole period. For this there were two main reasons : officers experienced enough to impart their knowledge to others were few and far between, and difficult ENT cases upon which trainees could be taught were rare in proportion to the mass of cases requiring comparatively simple routine treatment. Trainees who had not previously done house appointment in a busy civilian hospital and thus attained a solid background, could not after a few months of training be trusted alone to deal efficiently with difficult mastoid surgery or endoscopy.

Nursing Officers : Though there were many sisters with special ENT training, it was not considered necessary to recommend their posting to ENT centres. Army ENT cases do not present difficult nursing problems. It was considered that the average nursing sister was capable of doing all that was required.

Orderlies : The number of out-patient cases encountered in India suffering from sub-acute or chronic suppurative otitis media and otitis externa was very high. Such cases would only respond quickly to treatment when individual attention was given daily or even twice daily. Specialists had not the time to render such service, so that the role of an orderly was extremely important. There was no establishment for ENT orderlies either in centres or BGHs. On the other hand the senior NCO on the establishment of an Indian surgical unit (ENT) held the rank of sergeant. The anomaly, despite representations from the consultant and advisers, was not rectified.

The intelligent Indian or British other rank was not encouraged to make himself interested in ENT work knowing that his only chance of promotion lay in other directions. It was a constant source of worry to specialists, who had trained a good orderly, to know that change was inevitable sooner or later. As a saver of manpower the good ENT orderly interested in his work and proud of his responsibility was worth his weight in gold.

EQUIPMENT

During the 1942-43 expansion of medical services, shortage of equipment was extremely serious. The then consultant to the Southern Army and adviser to the GHQ was confronted with a difficult problem. Equipment scales had to be laid down for the newly formed centres and surgical units (ENT), keeping in view the inability of the United Kingdom to provide such equipment.

The scales laid down erred on the side of redundancy and in some respects were more generous than BGH equipment (scale 1-1248). Complications arose because centres and surgical units (ENT) had to be equipped on one scale differing in detail, whilst BGH equipment replacements had to be made good according to the British scale (1-1248).

In 1942, more than one centre depended almost entirely upon the generosity of the specialist in charge who used his own instruments, whilst more specialists had to show initiative in getting certain things constructed locally.

It was decided that Indian factories must be asked to manufacture many of the most essential examination and operating instruments. After considerable delay these were produced, but the quality, because of lack of suitable material, was so bad that a high proportion had to be condemned as unserviceable.

The ENT equipment was concentrated in the Army Medical Stores, Bombay.

There was a steady improvement in the equipment position during 1944 and 1945. The consultant's recommendation, that one scale of equipment identical with that of a BGH (scale 1-1248) should be adopted, was given official sanction, the necessary alterations were made in the PVMS bringing it into line with the War Office PLME. By the spring of 1945, even endoscopy instruments were no longer in short supply.

Throughout the whole period there were often difficulties with auriscopes which were not made to a standard pattern. Replacement bulbs and batteries often would not fit.

ACCOMMODATION

The accommodation, necessary for an army ENT out-patient department, need not be elaborate. As long as adequate floor space is available, a method of darkening the room and the requisite electrical points can be arranged. Good clinics, therefore, functioned without difficulty. There were particularly good departments at Poona, Bangalore, Rawalpindi and Secunderabad which lent themselves to teaching in addition to routine work.

CLINICAL

Indian Troops: In addition to otitis externa, otitis media, and tonsillitis, simulated deafness was commonly encountered and in some areas assumed serious proportions. There was a well recognised routine amongst malingerers. Some irritant such as the 'marker nut' was applied to the meatus with a long dirty fingernail. When the resultant external otitis was established and discharge was obvious, complete deafness was simulated, Some would grind up mepacrine tablets in antigas ointment and use this to irritate the meatus.

Medical Directorate, India, *Technical Instruction No.* 27 was issued to medical officers emphasising the importance of early recognition of malingering and the institution of disciplinary action before admission to hospital was considered.

Amongst Indian troops, it was considered better to board out cases of recurrent otitis media rather than to downgrade them. Duties at base were often without interest and sufferers were too often encouraged to make the most of a comparatively slight disability.

British Troops: The great majority of British troops seen at ENT centres were suffering from otitis externa, otitis media and tonsillitis. Sinusitis was on the whole uncommon. It was evident even up to the cessation of hostilities that the combing out of cases suffering from chronic otitis media before overseas service was not always effective. Simulated deafness was rare, and self-inflicted otitis externa unknown. Atrophic rhinitis with crusting was very rare, but all sufferers had to be sent to the United Kingdom because flies made life intolerable for them. Gunfire deafness presented many problems; protection in the form of ear plugs was adopted by some units but in practice personnel preferred not to use them because orders from command post could not

be heard. Ear plugs in hot climates contribute to the incidence of otitis externa.

The wastage of British troops on account of ENT diseases was not high, though many cases had to be downgraded as a result of unhealed drum perforations and recurrent otitis media. Soldiers suffering from such disability could usefully perform garrison duties but were a liability in the forward areas.

Care had to be exercised to comb out men who suffered from complete deafness in one ear though the drum was intact and hearing was standard II. Regulations allowed such men to remain in Category A 1, yet they were a danger to themselves and others in the jungle when the sound of a snapping twig had to be heard and accurately localised.

West African Troops: Chronic suppurative otitis media was the commonest disease which called for specialist attention.

SULPHONAMIDES AND PENICILLIN

Recognition of pitfalls associated with the use of sulphonamides in cases of acute otitis media was rather tardy in India. Too frequently cases of acute mastoiditis were encountered in which signs and symptoms had been masked by inadequate dosage or the late institution of treatment. Medical officers were late in accepting the well known fact that these drugs were useless in cases of chronic otitis media.

As a local application to the meatus in cases of otitis externa or even otitis media, sulphonamides being insoluble do more harm than good. Medical officers and even some specialists learned this lesson too late.

Penicillin was not issued to the Army in India until 1944, and even then the quantity of available was small. The value of penicillin in cases of acute otitis media might have been recognised, but the drug was too valuable to be issued for investigation. Supplies became available late in 1944 for cases of complications of ENT diseases such as lateral sinus thrombosis and osteomyelitis of the frontal bone and its use in such cases was fully justified.

BATTLE CASUALTIES

Battle casualties requiring the ministrations of an ENT specialist at an early stage are not common. Shell and bomb splinters which have entered the nasal accessory sinuses without fatal results can usually be removed after many days when patients have been evacuated from forward areas. Splinters buried in the mastoid process might pierce the lateral sinus, but more often they remained in the cortex without immediate harm. Interference was not necessary under such circumstances, till patients were evacuated. Many days and often weeks could elapse before expert surgical treatment was required. Blast injury to the tympanic membrane was as common as in any other theatre of war but the correct disposal of such cases depended upon the RMOs. As soon as it was recognised that ear was damaged it was covered by a

first field dressing and left severely alone, subsequent otitis media became less frequent and secondary mastoid involvement comparatively rare.

Gunfire deafness presented a comparatively small problem in forward areas ; in the heat of battle soldiers would go on fighting without realising the extent of their disability. The worst cases were evacuated in the ordinary way and dealt with in the base hospital centres. Thus it was demonstrated that ENT specialist cover in the forward areas is of much less importance than ophthalmological specialist cover.[2]

REHABILITATION OF DEAF SOLDIERS

Just before the cessation of hostilities, this problem was being given serious consideration and attempt was made to organise a hearing aid centre at Secunderabad. The difficulties were great because only a few good aids could be expected. Immediate establishment of a large organisation of training in lip reading for Indian troops was not a practical proposition on account of the diversity of languages.

ROLE AND LOCATION OF ENT UNITS

Planning of ENT services for an army fighting with long lines of communication is less complicated than planning for ophthalmological services.

Considered in detail the role of military ENT units varies according to their attachment to forward units, line of communication units and base hospitals or garrison hospitals.

Forward Units : Surgical units (ENT) attached to forward field hospitals serve a useful purpose in preventing the seepage backwards of many cases which could be rendered fit for front line fighting after a short period of specialist treatment. Otitis externa serves as an illustration. It is an unfortunate fact that this common and far from serious condition should present such a problem to those without special training in ENT diseases.

By the uninitiated it is often wrongly diagnosed as acute mastoiditis, or, if spotted, is treated in such a way that the disease becomes chronic and intractable. As a further example, soldiers would develop infection of an antrum following the common cold. A comparatively short stay in hospital for therapeutic punctures followed by a period of rest would render them fit.

The ENT specialist attached to a forward field hospital suffers badly from the monotony of treating simple cases and of being largely divorced from the interest of practical surgery. It is axiomatic that more experienced specialists shall not be appointed to hold such posts

[2] Also see Clark, J. V. (1946). *J. Laryngology and Otology*, **61**, 586.
Daggett, W.I. (1946). *J. Laryngology and Otology*, **61**, 508.
Moffett, A. J. (1943). *J. Laryngology and Otology*, **58**, 453.
Moffett, A. J. (1944). *J. Laryngology and Otology*, **59**, 151.
Moffett, A. J. (1945). *J. Laryngology and Otology*, **60**, 415.

and it is desirable where possible to arrange reliefs to prevent young officers becoming disinterested.

A more constructive approach would be to organise courses for all general duty medical officer before posting to forward areas and to see that they are conversant with diagnosis and treatment of the simple ENT complaints. Equipment provided for their use need not be elaborate.

Line of Communication Units : There need be no ENT units located at staging points, but units at advanced base hospitals will prove useful if such hospitals are situated where there is a considerable concentration of line of communication troops.

Base Hospitals and Garrison Hospitals : It has already been pointed out that an efficient ENT service can be organised without segregating battle casualties from garrison sick. The centres can be located in either IMHs, BMHs or IBGHs whichever provide the accommodation. The high proportion of walking sick renders attendance of patients for treatment at the centre a comparatively easy matter. An ENT specialist works more efficiently and economically when using static equipment. He must, however, be provided with facilities for operating in adjacent hospitals.

In a country as vast as India the problem of the care of outlying garrison sick requires careful consideration. In general the touring specialist is a specialist wasted. Nothing can be more dangerous than the practice of a specialist travelling 48 hours, performing six tonsillectomies and leaving at once. Subsequent haemorrhage, often difficult to control, may be followed by disaster. It is essential that 'cold surgery' should be taken to the specialist, and that the centre at which he works should not be left to look after itself for days on end.

Touring is sometimes unavoidable but it must be kept down to a minimum, and efforts must be made to collect together at outstations all cases requiring an opinion. As regards genuine emergency cases, specialists can now often be transported by air to deal with those which cannot be moved, whilst many urgent cases can be flown to the centre without running more than an insignificant risk. Acute mastoiditis serves to illustrate this point. It is safe in these days of chemotherapy to fly such cases hundreds of miles to a well equipped centre. The dramatic emergency case requiring tracheotomy must be dealt with by the medical officer on the spot, and the question of sending a specialist or transferring the case does not arise.

CHAPTER XXXV

Peripheral Nerve Injuries Centres

INDIAN TROOPS

Up to November 1943, the majority of peripheral nerve injuries from the Arakan were transferred to No. 3 Mobile Neurosurgical Unit in Bareilly. Before the movement of this unit to a forward area at the end of 1943, a centre for peripheral nerve injuries, with Indian and British wings, was planned. It was agreed that each wing of the centre should be attached to an orthopaedic hospital, as a high proportion of nerve injuries were complicated by bony damage, and use could be made of the existing facilities for physiotherapy, rehabilitation and occupational therapy. The Indian and British centres, however, actually worked in different stations. The work of the centres was supervised by the consultant neurologist and consultant surgeon, India Command.

The chief interest in the clinical material lay in the high proportion of causalgia. The incidence of this complication was more than twice that reported in Britain, South Africa and the USA. After a preliminary trial of novocaine injection in each case, large number of cases were ramisected with complete relief of pain. Few cases required nerve grafts, and mobilisation of nerves was in general sufficient to enable direct suture. Following the introduction of penicillin many cases of nerve section were sutured in forward areas, especially in Comilla, with excellent results.

No. 7 IBGH, Kirkee was selected as the home of this centre and the first lot of cases arrived early in 1944. The choice of site was a very appropriate one since the hospital was already doing a great deal of orthopaedic work and was fortunate enough in possessing a well equipped rehabilitation centre where facilities for electrotherapeutic treatment as well as diversional therapy were available.

It is estimated that at least 923 cases of nerve injuries were treated in the hospital. Of these records of 613 are available. The extent of the problem was tremendous not only because of the large numbers involved but also because of the type of the patient. It was extremely difficult for the patients to understand why their seemingly minor wounds required more prolonged treatment than the more serious wounds of their comrades involving fractures of bones. All efforts to explain to them the nature of their injuries were of no avail. Invariably they attributed delay to unwillingness of the surgeon to give them effective treatment quickly. In their opinion rehabilitatory exercises and electro-therapeutic treatment was no treatment at all. They could not understand the reason for staying in hospital for observation after the operation had been performed. This to them was absolutely unnecessary since they assumed that recovery would be automatic after the operation. A good few of them refused treatment during the early period of observation and had to be discharged. Others stayed on till the operation

was performed and then started being difficult. Still others waited till first signs of recovery had become evident. They were under the impression that once recovery had started it was only matter of time for it to become complete. Unfortunately, there were no means of contacting the patient once he was discharged.

Another feature worth emphasising is the marked element of psychoneurosis which existed in a large number of them. This rendered sensory findings completely unreliable. In others even exaggeration of motor paralysis existed making exact estimates of the extent of motor paralysis extremely difficult.

CAUSATION

Missile injuries of one type or another formed the bulk of cases. The rest were accidents. The frequency of various missiles producing nerve lesions is given below. Grenade wounds, even when they produce minor superficial wounds, are quite capable of producing serious nerve lesions.

Gunshot wounds	293
Shell, mortar or bomb wounds ...	179
Grenade wounds	85
Accidents	55
Bayonet wound	1
Total	613

Nerve injuries classified according to nerves involved are given in Table I.

TABLE I

Nerve injuries classified according to nerves involved—Indian troops.

Nerves	Single	Multiple	Total	Percentage
Ulnar	242	68	310	30·21
Radial	174	50	224	21·83
Median	108	82	190	18·52
Brachial plexus	56	...	56	5·46
Sciatic	114	...	114	11·11
Peroneal	111	...	111	10·82
Tibial	16	...	16	1·56
Femoral	5	...	5	0·49
Total	826	200	1,026	100·00

It will be seen that ulnar nerve seems to be the one most frequently involved.

TREATMENT

The general policy of treatment was to explore cases as soon after the wound had healed as possible and deal with the nerve according to the findings at the exposure. This policy could not always be put into practice on account of various reasons; mainly because of delay in arrival of patients at the centre. The fronts were far flung, ranging from Middle East and Italy in the west to Burma in the east. Lines of evacuation were long and delay was inevitable.

By the time the cases arrived, some of them were showing signs of spontaneous recovery. Where this was well advanced, operation was delayed to allow the nerve to recover by itself as much as possible. The only treatment provided in such cases consisted of supports to prevent overstretching of muscles, active movements and exercises to keep up nutrition of muscles as well as galvanism once a day. The conservative treatment was necessitated by an excessive accumulation of cases who were showing no signs of recovery and, therefore, had to be explored and was justified by results. Of the cases treated on conservative lines 114 completely recovered. This will be evident from Table II.

TABLE II

Spontaneous recovery of peripheral nerve injuries—Indian troops.[1]

Nerves	M3 S2	M2 S2	M1 S2	Total
Ulnar	12	19	...	31
Radial	21	8	...	29
Median	4	7	...	11
Axillary	...	...	...	3
Sciatic	...	4	5	9
Peroneal	...	5	8	13
Tibial	...	2	5	7
Femoral	...	...	...	3
Brachial plexus	...	...	...	8
Total	37	45	18	114

The remaining cases who were showing no signs of recovery were submitted to operation. The subsequent treatment depended upon the findings during exploration. Completely divided nerves were sutured, if end to end approximation without tension could be secured. Material used for suture was linen or silk. No other material was available. Where end to end approximation was not possible, nerve graft of one type or another had to be resorted to.

Cases, where there was no actual division of the nerve and a soft fusiform neuroma marked the site of damage in the nerve, presented a

[1] For explanation of symbols used in assessment of recovery see pages 730–31.

difficult problem. It was not easy to decide the extent of damage to nerve fibres coursing through the neuroma even with the help of faradic stimulation. Conduction of faradic stimuli through the neuroma resulting in muscular contraction merely established that some of the fibres were intact, but was no guarantee that certain others were not divided. Usually the neuroma was explored and if fibrous tissue was found to be in excess of intact fibres, a secondary suture after excision of neuroma was performed. Owing to extensive fibrosis, the neuromas were usually large and dissection of divided fibres out of the mass of fibrous tissue was neither easy nor devoid of risk to the intact fibres.

Delay in prompt exploration was also caused by associated lesions, e.g., extensive loss of skin, persistent sepsis, compound fractures, etc. It was thought safer on the whole to obtain bony union first to avoid damage to the nerve during operation of bonegraft. Contractures of the fingers were most difficult to treat and caused the greatest delay. At first, on account of the time taken to reach the centre, the percentage of such cases was high; later, however, the cases started arriving earlier.

PATHOLOGICAL FINDINGS

The types of lesion encountered were numerous. Interruption of nerve conduction without actual division results in various ways. Fibrosis around and in between the nerve bundles giving rise to soft neuromas or a band of fibrous tissue tacking the nerve to surrounding structures were frequent causes. At other times the nerve was found to be adherent to the surrounding structures over a wide extent. Callus produced by the fractures in the vicinity of a nerve interfered with the conductivity of a nerve, e.g., ulnar behind the medial epicondyle. In malunited fractures of long bones producing extensive callus, the nerve though not coming in direct contact with the bone had its function interfered if it was passing over the ' bump '. The nerve at the site of the ' bump ' showed a little thickening; the sheath of the nerve was thickened, glistening white and opaque while the distal portion of the nerve was considerably reduced in diameter. Complete but short lived interruption of sciatic nerve resulted in one case of a BOR who shot himself accidentally, the bullet entering the groin and escaping through the buttock. On examination before the operation, there was complete paralysis of all muscles supplied by the sciatic nerve. During exploration of the nerve it was noticed that the nerve was intact, but there was a collection of blood under the sheath of the nerve. This was evacuated with the help of a syringe. Within a fortnight the nerve was showing signs of recovery, and at the end of six weeks practically all muscles were functioning, though weak, and sensation was returning. Narrow fibrous band very often resulted from grenade wounds and attached nerves to surrounding structures.

Actual division of nerve presented several appearances at exposure. Complete division with no connection between proximal and distal neuromas was not as common as might be expected. When it occurred the neuromas were widely displaced. More often the neuromas maintained connection with each other through fibrous tissue. The two

neuromas in some cases were continuous and appeared as one on account of extensive fibrosis. Considerable confusion was caused in others by the appearance of the two ends of a divided nerve entering a bone. This happened often with radial nerves in the musculospiral groove and was due to the incorporation of the nerve ends in the callus resulting from fractured humerus.

Ischemic lesions were seen in the median nerve only. The nerve had a bulbous end, the distal portion being continued in a very attenuated form. There was no actual division.

POST-OPERATIVE TREATMENT

Limbs operated upon for nerve suture had to be in one posture in plaster of paris for prolonged periods to prevent tension on the suture line. Usually a period of six to eight weeks was allowed. During this period movement of available joints was encouraged. Arm cases could walk to the physiotherapy centre while the leg cases received treatment in bed. After removal of the plaster patients were gradually allowed to extend the joint by themselves. Forcible or arbitrary adjustment of angle of the joint was never done. Left to himself the patient took from two to three weeks to fully extend the limb. Galvanism was started as soon as the plaster was removed and gradually the patient started exercises. Repeated examination of voluntary power and faradic and galvanic responses were made during the period of recovery and efficient splintage was kept up.

RESULTS

All results given below are interim results. There were practically no arrangements for a follow up and, on account of large numbers involved, it was not possible to keep patients indefinitely in the hospital. They were kept as long as possible because it was obvious that a discharged case would be a lost case. Maximum period of observation never exceeded 18 months, sometime not more than nine to ten months. Results would have been better if the usual follow up of three years had been achieved.

The cases were classified according to the system (the clinical system) recommended by the MRC of England as under :—

Assessment of sensory recovery :

S.0. No recovery in the autonomous zone of the injured nerve.

S.1. Recovery of deep cutaneous pain in the autonomous zone.

S.2. Return of some degree of superficial cutaneous pain and touch sensibility within the autonomous zone of the nerve.

S.3. Return of superficial cutaneous pain and touch sensibility throughout the autonomous zone with disappearance of any over-response.

S.4. Return of sensibility as in stage 3 with the addition that there is recovery of two point discrimination within the autonomous zone.

Assessment of motor recovery :—

M.0. No contraction.

M.1. Return of perceptible contraction in the proximal muscles.

M.2. Return of perceptible contraction in both proximal and distal muscles.

M.3. Return of function in both proximal and distal muscles to such an extent that all important muscles are of sufficient power to act against resistance.

M.4. Return of function as in stage 3, with the addition that all synergic and isolated movements are possible.

M.5. Complete recovery.

A certain amount of difficulty is felt in the application of this method, since muscular recovery does not lend itself easily to classification. There were several cases that did not fit into any of the above categories. For example, a case may not be quite M. 2, since the whole of the distal group has not recovered, but it is neither M. 1, because a few muscles have recovered in the distal group. Also an M. 1 case may not stop at perceptible contraction, though there may be no recovery in the distal group. These figures, translated into actual utility of the limb, do not mean the same thing. M.1 in the case of sciatic nerve, where distal group of intrinsic muscles of the foot very seldom recover, means a great deal more than the same group in any other nerve. The ultimate utility of a limb depends a great deal on sensory recovery too. Good muscular recovery unaccompanied by sensory recovery would be a handicap rather than advantage. Anaesthesia of the hand exposes it to severe burns and the same in the foot would lead to perforating ulcers. Recovery of nerves, therefore, has to be expressed in a composite formula representing both muscle power and sensation.

For purposes of classification, where a muscle recovery could not be placed squarely in a particular group, it was put in the next lower group. For example, a muscle, showing good recovery in the proximal group and only partial recovery in the distal group, was put in the M. 1 group and not in the M. 2 group.

Out of 923 cases nearly 200 recovered fairly good function spontaneously. Of these, 114 were very good recoveries in as much as both proximal and distal group of muscles recovered and sensation returned.

Tables III and IV give the results of neurolysis and secondary nerve suture.

Results of neurolysis show that a certain number did not make as good a recovery as expected. The actual number was 16 out of a total of 102 cases. No second explorations to ascertain the cause of lack of recovery were carried out, since the patients did not consent to a second operation. These were lesions in which on dissection of neuroma it was decided not to perform secondary suture.

Suture recoveries were fairly encouraging. Ulnar seems to be the worst nerve from recovery point of view. Site of lesion does not seem to make much difference.

TABLE III.

Results of neurolysis—Indian troops.

Nerves	Site of lesion	M3 S2	M3 S0	M1 S2	M1 S1	M1 S0	M0 S2	M0 S0	Total
Ulnar	Arm	5	1	2	...	4	2	4	18
	Forearm	...	...	8	...	9	2	2	21
	Wrist	...	...	...	...	...	...	2	2
Median	Arm	4	1	5	...	7	...	3	20
	Forearm	1	...	...	...	2	...	...	3
Tibial	Thigh or Knee	...	...	8	3	9	...	1	21
Peroneal	Thigh or Knee	...	...	10	...	3	...	4	17
Total		10	2	33	3	34	4	16	102

TABLE IV.

Results of secondary suture—Indian troops.

Nerves	Site of lesion	M3 S2	M1 S2	M1 S1	M1 S0	M0 S2	M0 S0	Total
Ulnar	Arm	1	2	...	2	1	8	14
	Forearm	...	...	...	3	4	8	15
	Wrist	...	2	...	...	...	1	3
Median	Arm	...	3	...	1	...	1	5
	Forearm	...	2	...	1	...	...	3
Radial	Arm	9	6	...	...	...	...	15
Tibial	Thigh	...	4	4	1	...	1	10
Peroneal	Thigh	...	7	3	4	...	9	23
Total		10	26	7	12	5	28	88

For the sake of convenience, sciatic lesions were treated as separate lesions of peroneal and tibial nerves since the nerves are separate. Peroneal

was found worse than tibial from recovery point of view. A large number of poor recoveries was accounted for by large gaps as shown by Highet and Holmes (1943) and Highet and Sanders (1943). If the gap is more than 11 cm. post-operative stretching, no matter how carefully carried out, damages the nerve by traction.

Certain nerves presented peculiar problems in as much as secondary suture was not always possible in them. Dorsal interosseus of the radial was one of them. Owing to extensive scarring common in battle casualties as well as the small size of the nerve, it was considered better to deal with this by tendon transplantation. The same applied to those cases of radial lesions in the arm in which all muscles did not recover.

The technique employed, in the beginning, was that recommended by Sir Jones (1917). It was soon realised that the results were not satisfactory in spite of intensive post-operative rehabilitation treatment and re-education. It was noticed that the power of flexion was lost in the wrist, if both the flexors of the wrist were used. Long flexors of the digits, on which the operation relied for flexion of the wrist, were not capable of performing this function. This was also pointed out by Zachary (1946) in an analysis of series of cases performed at Wingfield-Morris Orthopaedic Hospital at Oxford between 1940-45. It was realised that to retain flexion in the wrist, one flexor tendon at least must be left behind. Where palmaris longus was present flexor carpi radialis was left behind. In the absence of palmaris longus reliance had to be placed entirely on flexor carpi ulnaris. This operation, combined with early mobilisation, gave the best results.

AXILLARY NERVE

This may be considered along with those cases of brachial plexus lesion, which involved fifth and sixth cervical only, and in which either suture was not possible or no recovery occurred. For cases in which deltoid paralysis was either the only lesion or residual lesion, an extra-articular arthrodesis of shoulder according to Britain's technique was carried out. A tibial graft was inserted and fixed to scapula at one end and humerus at the other. Provided the suprascapular and rhomboids were not involved, this operation restored power of abduction to the shoulder.

In cases where lesion of sixth cervical was present giving rise to paralysis of flexors of the elbow, the latter joint had to be arthrodesed. In one case, where the lesion involved fifth, sixth and seventh cervical, not only the two procedures outlined above had to be carried out, but in addition tendon transplantation had to be performed to rectify paralysis of the extensors of the wrist.

SCIATIC

Unrecovered tibial was a hopeless problem on account of anaesthesia of the sole of foot. Any effort at weight bearing or ambulation resulted in trophic ulcers. Peroneal, however, was not so depressing since the foot-drop could be permanently remedied. The best means of doing so was to perform a subastragaloid arthrodesis of Lambrinudi. A

satisfactory fusion of bones was obtained in all cases. In view of the conditions prevailing in villages to which the soldiers had to return, it was considered unlikely that they would wear permanent foot-supports. In fact, they resented the very idea and were very grateful when their feet were permanently fixed for them.

NERVE GRAFTS

Only in a limited number of cases in which nerve ends could not be approximated, the gap was bridged by this method. Most of the cases were not willing to stay long enough in the hospital. Some of them had to be discharged on their insistence thus reducing the number actually observed. Brief case summaries of seven cases given below would show the usefulness of this procedure.

Case 1—Median Nerve Graft (Whole Nerve) : R/M. D.R. 1/7 G.R. sustained machinegun wounds of right arm on 21 March 1944. Arrived at the centre on 16 September 1944. Complete median and ulnar lesion in the arm. An extensive puckered scar on the medial aspect of the arm with considerable destruction of muscles underneath. Within the next two months a skin tube was constructed on his chest and transferred to his arm. Arm explored on 15 November 1944. Both median and ulnar found divided. Ulnar gap 12 cm. and median 10 cm. Whole nerve graft removed from the proximal ulnar and inserted into the median. Graft 10 cm. long. Sutured with silk. First sign of recovery appeared in January 1946, fourteen and a half months after the operation. Discharged on 31 October 1946, because he refused to stay any longer. Condition was as follows :—

Muscles	
Pronator teres	3
Flexor carpi radialis	4
Palmaris longus	4
Flexor digitorum sublimis	3
Flexor digitorum profundus	3

Also had protopathic sensation in the palm. Recovery—M1 S1.

Case 2—Median Nerve Graft (Whole Nerve Graft): Sepoy S.S. 5/1 P.R. sustained grenade wound of left forearm on 19 April 1944. Arrived at the centre on 20 October 1944. Explored on 29 November 1944. Complete lesion of both ulnar and median in the forearm, with gaps of 12 cm. in each. Nerve graft removed from proximal ulnar and inserted into median. Length of graft 3·5 cm. Sutured with silk.

No recovery at all. Probable cause—traction damage on account of short graft.

Case 3—Ulnar Nerve Graft. (Cable Graft) : R/M P.B. (4/4 G.R.) sustained GSW of left arm on 12 March 1945. Arrived at the centre on 22 June 1945. Explored on 17 September 1945. Revealed a complete lesion of ulnar in the arm. Gap 17 cm. Medical cutaneous of the arm used as donor. Due to the gap only two strands could be

inserted. Sutured with silk and buried in muscle. Discharged on 18 November 1946 on account of disbandment of the centre. The following muscles were acting.

Flexor carpi ulnaris	...	3
Flexor digitorum profundus	...	3

Also had protopathic sensation in the hand. Recovery—M1 S1.

Case 4—Tibial Nerve Graft (*Cable*): L/NK L.B.G. (1/5 G.R.) sustained GSW of left knee on 14 December 1943. Arrived at the centre on 9 July 1944. Exploration, done on 5 August 1944, revealed a complete lesion of both tibial and peroneal. The latter was sutured. Tibial gap 11 cm. Lower neuroma between the two heads of gastrocnemius. Posterior cutaneous of the thigh used as donor nerve. Cable graft inserted and sutured with silk. Discharged on 2 November 1945. Gastrocnemius was acting (3) but there was no recovery of sensation at all.

Case 5—Peroneal Nerve Graft (*Cable*): Gnr. K.S. (RIA) sustained mortar wound of left knee resulting in compound fracture of femur on 18 January 1945. Arrived at the centre on 13 September 1945. Fracture united but had lesion of peroneal nerve. Exploration, done on 6 February 1946, revealed a completely divided nerve. Gap 12 cm. Sural used as donor and three lengths of 5 cm. each inserted and approximation obtained with flexion of knee. Sutured with silk and buried in muscle on 26 November 1946. No recovery.

Case 6—Peroneal Nerve Graft (*Cable*): Sep. B.S. (5/16) P.R. sustained GSW of left thigh on 26 August 1944. Arrived at the centre on 11 January 1945. Exploration, done on 13 June 1945, revealed a completely divided peroneal nerve with a gap of 9 cm. Approximation was not possible on account of limitation of knee flexation due to fracture of femur. Sural used as donor and a cable graft inserted. Sutured with silk on 4 September 1946. No recovery at all.

Case 7—Peroneal Nerve Graft (*Cable*): Sep. 4/5 (M.L.I.) sustained grenade wound of right thigh resulting in fracture on 6 June 1944. Arrived at the centre on 12 May 1945. Fracture united but marked limitation of knee flexion persisted. Exploration, done on 3 June 1945, revealed a completely divided peroneal nerve with a gap of over 3 cm. Approximation not possible on account of limited knee flexion. Posterior cutaneous nerve used as a donor. Cable graft sutured with silk on 26 November 1946. Peronei were acting (3) but there was no recovery of sensation.

CAUSALGIA

The management of causalgia following injury to peripheral nerves constituted an important problem in the treatment of nerve injuries. Up to the end of 1944, 32 cases of causalgia were received and treated. After 1944 the incidence fell steeply; only five cases were received including three mild cases. It was about this time that penicillin became available in the front line units. It is

possible that penicillin by reducing the incidence of sepsis in the wounds, helped in the reduction of the incidence of causalgia. Very likely the amount of intraneural fibrosis was an important factor in the causation of causalgia.

Another notable feature was the high racial incidence. Gurkhas seemed to be peculiarly liable to develop this complication. Out of 32 cases, 18 were Gurkhas, a preponderance which cannot be easily explained. It was also noticed that in the presence of sepsis a large number of Gurkha cases had excessive scarring and keloids. On a particular day all Gurkha troops suffering from penetrating injuries were examined for evidence of scarring and keloids. It was found that 38 cases out of a total of 95 showed distinct evidence of one or the other. This observation tends to confirm the view expressed above that intraneural scarring has a very important bearing on the causation of causalgia. Very likely the determining factor is the amount of fibrosis in the divided central nerve and which in some way sets up altered type of stimuli which course to the central nervous system. For example in some cases this condition arose in spite of a complete severance of sciatic from the peripheral end. The altered stimuli coursing through the normal channels produce a final pattern of different shape in the central sensory areas.

The incidence of causalgia was rather high (2 per cent.), but this can be explained by the fact that some nerve cases were treated in other hospitals whereas almost all causalgia cases found their way to the centre. It is unnecessary to enter into a detailed description of the symptoms of causalgia since the condition is now well understood. A detailed account of the treatment, however, is given below.

Treatment : Mild cases of causalgia, where the patient was not much disturbed by his pain particularly at night, were treated by novocaine injections around the sympathetic trunk. In the case of upper extremity 5 cc. of 1 per cent. novocaine were placed around the sympathetic trunk below the level of stellate ganglion at one or two points. This avoided Horner's syndrome. In the case of lower extremity the injection was made around the lumbar sympathetic trunk with the quantity increased to 20 or even 30 cc. Injections were given weekly or biweekly depending on the severity of pain. As the pain settled down the injections were made less frequently.

In mild cases of the type described above the response was good. Pain disappeared for several hours or even a whole day and though it recurred it was milder after each injection. After about four injections the pain finally disappeared. Majority of the cases were followed up for at least eight months. In some cases the follow up period extended to one and a half years.

Severe cases did not respond so well. Though the pain disappeared completely soon after the injection, it returned within an hour or so. These cases had to be submitted to operation.

In the upper extremity the sympathetic trunk was divided below the level of third dorsal ganglion and second and third rami were resected. In lower extremity the second and third lumbar ganglia

with the intervening trunk were removed. In both cases preganglionic fibres supplying the limbs were divided. In the lower extremity the operation did not attain a complete denervation of the limb, but experience showed that results were good. Apparently, the relief of causalgia did not require a complete denervation of the limb. The operation was an extra-peritoneal exposure of the trunk through an oblique incision in the loin. There were five such cases.

Sixteen cases involving the upper extremity were submitted to operation. In 14 cases the anterior root of Leriche was adopted. It is true that one cannot deal very effectively with the trunk through the anterior root. The posterior root permits one to deal effectively with the second and third dorsal nerves as recommended, by White and Smithwick. Regeneration of fibres, for the sake of which the posterior root is recommended, does not seem to have made much difference to the relief derived from this operation. More than half the cases remained under observation for over a year and there was no recurrence of pain. In the other two cases the root used was posterior (ADSON's).

BRITISH TROOPS

The peripheral nerve injuries centre for Britsh troops came to life in December 1943 at No. 3 IBGH(BT), Poona in response to increasing demands for a specialised unit where wounded with long term injuries could receive adequate treatment. Poona was chosen in order that the surgical specialist in charge of the centre could at the same time advise his Indian colleagues who supervised the IORs at the peripheral nerve injuries centre at No. 7 IBGH (IT), Kirkee. This close and happy relationship between the Indian and British centres lasted for a year until in December 1944, the British centre was moved to No. 128 IBGH (BT) at Secunderabad.

The British centre was perhaps unique in that while there was never an official establishment, nonetheless the centre was able to retain its personnel and to maintain its individuality for almost two years. In the end, it faded away much in the same way as it grew; it was not officially disbanded—indeed it could not have been since it had never been officially established. Its happy position was due in no small measure to officers commanding Nos. 3, 126, and 128 IBGHs (BT).

While there was no official establishment, it came to be recognised that the team consisted of one surgical specialist, one surgical general duty officer and four physiotherapists. This team remained intact for over a year, when the move to Secunderabad involved the separation of patients into two groups, one remaining at Poona and the other moving to Secunderabad; one physiotherapist was left for those who remained at Poona, pending evacuation to Britain; another physiotherapist then joined the centre. In May 1945, the surgical general duty officer became a graded surgeon and moved to Ranchi to open a second peripheral nerve injuries centre before the final assault in Malaya.

There were admitted 665 patients in the course of 25 months. The rate of admissions (Table V) reflects the course of the war, and at the

same time indicates the care with which peripheral nerve injuries were segregated in the forward areas and the speed with which they were evacuated to the centre ; a considerable number were admitted to the centre within one week of receiving their wounds in Burma. To Brigadier John Bruce, consultant surgeon, Fourteenth Army, must go every credit for organising this quick evacuation. Large convoys threw a heavy load on the staff, and with the accurate documentation required for nerve injuries, it was sometimes a week after admission before all patients were fully examined. The largest number of patients receiving treatment at any one time was 167, a total which could not be adequately treated by a physiotherapy staff of four; that almost all patients who were evacuated to Britain left the centre with mobile joints is due entirely to the loyalty and enthusiasm of those members of the Chartered Society of Physiotherapists who worked in the centre. Unfortunately, a number of these patients were delayed for prolonged periods during evacuation and suffered as a result, reaching Britain with stiff joints through lack of supervision.

TABLE V

Monthly admissions (actual number) to the Peripheral Nerve Injuries Centre (British troops) during December 1943 *to December* 1945.

Months	1943	1944	1945
January	—	8	18
February	—	8	20
March	—	16	54
April	—	24	79
May	—	43	19
June	—	91	36
July	—	89	11
August	—	35	8
September	—	25	7
October	—	22	3
November	—	11	5
December	21	12	...
Total	21	384	260

The nerves involved and the disposal of the patients are shown in Table VI. A number of patients had more than one nerve injured, but for convenience the most important nerve had been selected ; median had taken precedence over ulnar, and ulnar over musculospiral. In the category 'Miscellaneous' are included 14 cases of purely vascular injury, five cases of facial nerve paralysis and a number of nerve disorders which were transferred to the neurological centre. It will be seen that 238 patients returned to duty in India, and that nearly one-half (102) returned in category A; of these, 66 were either ulnar or musculo-spiral nerve injuries, the majority result of 'near misses' in through-and-through bullet wounds, although a number were simple pressure

palsies which recovered quickly and completely. That 117 of those who returned to Britain were recovering before they left the peripheral nerve injuries centre is an indication of the slow rate of evacuation which was dictated by the shortage of shipping ; the greater number were lesions in continuity, but a few were nerve sutures whose evacuation was unduly delayed.

TABLE VI

Disposal of 665 *patients with peripheral nerve injuries—British troops.*

Nerves involved.	Returning to duty in India.			Evacuated to Britain.		Total
	Category A.	Category B.	Category C.	Re-covering	Not re-covering	
Brachial plexus ...	7	8	9	16	8	48
Median	15	16	12	29	75	147
Ulnar	40	15	32	29	72	188
Musculospiral ...	26	6	7	17	46	102
Dorsal interosseus ...	4	1	3	—	8	16
Sciatic	1	1	5	16	32	55
Internal popliteal ...	—	—	—	6	7	13
External popliteal ...	8	2	15	3	17	45
Anterior tibial ...	—	—	—	1	1	2
Femoral ...	—	—	—	—	4	4
Musculocutaneous ...	—	—	3	—	3	6
Circumflex ...	1	—	1	—	2	4
Miscellaneous ...						35
Total	102	49	87	117	275	665

The number of peripheral nerves which were explored by operation was 157 ; resection and suture were performed on 83, while 74 underwent neurolysis only, including 11 patients on whom anterior transposition of the ulnar nerve was performed (Table VII). In addition, 19

TABLE VII

Operations on nerves at the Peripheral Nerve Injuries Centre (British troops).

Operations	Brachial plexus	Median	Ulnar	Musculo-spiral	Dorsal interosseus	Musculo-cutaneous	Circumflex	Sciatic	Internal popliteal	External popliteal	Anterior tibial	Total
Suture	–	19	29	11	–	–	–	8	6	10	–	83
Neurolysis ...	–	16	25	14	–	2	–	3	5	8	1	74

patients had sympathectomy carried out for causalgia, and five patients with irreparable damage to the dorsal interosseus nerve were submitted to tendon transplantation. Patients with apparently irreparable musculospiral nerve lesions were evacuated to Britain. Aneurysms, two arteriovenous, were excised in ten patients, with or without intervention on nerves. Two major amputations, numerous sequestrectomies, and many scar excisions were performed.

Many peripheral nerve injury patients required treatment other than that specifically directed towards the nerve lesion, and it was to their advantage that two sister branches of surgery were represented in the hospitals both at Poona and Secunderabad. Plastic repairs on skin defects were carried out at No. 2 Indian Maxillo-facial Unit, while fracture and other orthopaedic problems were dealt with at No. 3 IBGH when the centre moved to Secunderabad. A free interchange of patients took place between the orthopaedic and nerve injury units, because it became impracticable from the view point of numbers to retain in the nerve centre all those patients who had fractures in addition to nerve injury; they returned to the nerve centre for assessment when the fractures were united.

Although the numbers were smaller, the incidence of injury to the various nerves resembled closely that found in the larger civilian nerve centres in Britain, and in the American military nerve centres. The only divergence as compared with British centres lay in the proportion of patients who suffered from causalgia; there were 28 or 4·2 per cent., which is appreciably higher than that obtaining in Britain, although approximating the American figures. It is possible that the influence of environmental temperature accounted for this difference, for it was apparent that high day temperatures affected these patients materially, increasing the intensity of the burning pain; it was also apparent that cold afforded some measure of relief in the majority of patients with causalgia. The nerves involved are shown in Table VIII.

TABLE VIII

Causalgia; the nerves involved—British troops.

Brachial plexus	2
Median	12
Sciatic	8
Internal popliteal	2
Posterior tibial	3
Obturator	1

Causalgia had been found in World War I to be an intractable condition, but with the advent of sympathetic surgery it appeared that a satisfactory method of treatment was available. It, therefore, became routine to block by temporary novocaine injection the sympathetic chain to the limb involved; in all 28 patients relief was obtained and in 19

patients formal sympathectomy by operation was performed. Two patients appeared to have complete relief following repeated novocaine injections, one of them returning to full duty. Seven patients were regarded as having causalgia of an intensity which did not require surgical intervention. It was possible to investigate 22 of the patients with causalgia some two to three years later; 17 of the 19 who underwent operation were traced and found to be still free from pain; the two who had repeated novocaine injections were also free from pain; while of the seven who had no specific treatment, three were traced and found to be still suffering from mild causalgia, the intensity of which was only gradually diminishing.

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CHAPTER XXXVI

Radiology

APPOINTMENT OF CONSULTANT AND ADVISERS

The management of X-ray matters was in the hands of the Medical Stores Department during the early years of World War II. There were only ten radiologists who carried out normal duties in X-ray departments of military hospitals. By June 1941, considerable amount of money was being spent on X-ray equipment and accessories, and radiological work had also very much increased. It was, therefore, considered necessary to have an expert in radiology on the staff of the Medical Directorate. The varied questions regarding suitability of X-ray sets for CCSs and other medical units could then be referred to him for opinion and advice. He could also co-ordinate the work of various radiologists and ensure uniformity of procedure and policy. Accordingly a part time adviser in radiology was appointed on 16 July 1941.

By September 1942, it was apparent that a whole time adviser was essential. The appointment was made a whole time one with effect from 11 November 1942 with additional pay per month. The appointment was subsequently upgraded to that of consultant radiologist with the rank of brigadier from 31 October 1944. As expansion took place it became necessary to appoint advisers at headquarters of each command in India and an officer was also appointed as adviser SEAC. The appointment of these advisers was not entirely satisfactory as the officers occupying these posts were also radiologists at their headquarters stations and found it difficult to make frequent visits to X-ray units in their commands.

RADIOLOGISTS

In the meantime, subsequent to the increase in number of armed forces and the medical units serving them, the number of radiologists was also increased. By 1944, there were 126 radiologists, as against the authorised strength of 164, in the India Command and SEAC. The number of Indian X-ray units and Indian mobile X-ray units was 57 and 22 respectively in India, SEAC, Middle East and Persia and Iraq Command.

By January 1946, in India and South East Asia alone 133 IAMC and 24 RAMC radiologists were working in different units. Even then there was shortage of 11 IAMC and 52 RAMC radiologists. The problem of providing radiologists, however, was a constant cause of anxiety. It was not until the very end of the war that supply caught up with the demand. On 1 January 1947, there were 62 radiologists (including 39 graded radiologists) in the Indian Army allowed on the specific war establishments of static units. They were pooled and were posted in different hospitals in India. By 1 April 1947, there were

35 specialists in radiology working in different commands and one radiologist was in the Army School of Radiology.

TRAINING

There was no adequate arrangement before the war for the training of army personnel as radiologists or radiographers. Such radiologists as existed were officers and members of the subordinate medical services who had undergone training on their own initiative. Radiographers had received a rudimentary training in various military hospitals. Owing to the urgency of the demand, it was not possible in the beginning to give more than an elementary training, sufficient alone to make the officers and radiographers capable of looking after their apparatus. At first this training, limited to two months, was given in various headquarters stations in India, at which officers capable of undertaking the training happened to be situated. Gradually the training was concentrated at BMH, Lucknow, where a school for radiographers was established. In course of time the period of training was extended. Refresher courses were also established, to which it was endeavoured to send each officer at the end of each year after his preliminary training. At these courses the officers' capabilities and suitability for grading were also assessed. The same procedure was carried out in the case of radiographers. Ultimately sanction was obtained to establish an Indian Army School of Radiography, and this was opened in Secunderabad, and a course of training extending to nine months was begun.

EQUIPMENT

With the expansion of the medical services, it became necessary to supply X-ray equipment to the various new hospitals that were formed. To begin with this was on a very modest scale, and it was possible to obtain the equipment needed from the firms which had agents in India. In order to ensure standardisation of equipment, orders were placed with the same firm for future requirements as much as was possible. Financial reasons prevented the placing of orders in adequate number and by the time the financial considerations could be overcome, the world-wide demand for American equipment had become so great that such equipment was simply not forthcoming. The situation became further difficult as the India Command was placed low in the list of priorities for such equipment. As a result many hospitals on raising were short of X-ray equipment, and the standard aimed at, to have two X-ray sets of medium capacity and one portable ward set for each hospital, was never attained. In the winter of 1944-45, the consultant radiologist visited America in connection with the supply of apparatus, and after this, equipment and films were supplied in adequate amounts, but by the time they arrived in India the war was almost over. In order to enable forward hospitals to have X-ray facilities, a number of mobile X-ray units were formed. The transport consisted of two standard

three-ton military lorries, fitted up to carry standard X-ray equipment and tentage.[1]

STORAGE AND REPAIR

A special storage depot for X-ray equipment was established at Poona, and there the apparatus was received, overhauled, and then despatched to units as required, and a reserve of spare parts gradually accumulated. The facilities of the depot gradually expanded, until all ordinary repairs could be undertaken, and a few pieces of apparatus, otherwise difficult to come by, could be manufactured. In order to keep apparatus working in forward areas a staff of travelling electricians was established. These proved to be very useful. In India, they could make a regular six-monthly overhaul of apparatus. For the forward areas four travelling workshops were fitted up in Poona, and as they became available were allocated to divisions, and were invaluable. Unfortunately many more could have been utilised.

X-RAY FILMS

As great an anxiety as any which confronted the X-ray department was the supply of X-ray films. Films were imported by Ilford's Ltd. and by Kodak Ltd., and were stored under special arrangements in Bombay. This proved quite satisfactory so far as it went, and these firms were always most helpful and co-operative. The supply of films to the various hospitals and X-ray units had to be severely curtailed, as expansion progressed without corresponding expansion in the supply of X-ray films, and it was not until towards the end that it was felt possible to decentralise the supply to any great extent. This was most unfortunate, as the distances over which the supply had to be made were so great, and the delays on the railways so consistent, that the troubles of an inadequate supply were enhanced.

FUTURE REQUIREMENTS

It will be obvious that in future hospitals and field ambulances should have full X-ray equipment as part and parcel of their war establishment. This equipment should be of one make and type, and an adequate supply of spares should be maintained, and a suitable number of personnel should be trained as radiographers, sufficient to allow two radiographers to each unit. In addition a few mobile units should be maintained, carrying the same equipment as the stationary hospitals.

The supply of X-ray films in an emergency will be difficult, and it is suggested that the firms with suitable storage accommodation should be encouraged to maintain films sufficient for a full year's working, in excess of their requirements, which can be turned over regularly, and should not be a source of loss.

[1] Mass Miniature Radiography see Appendix A.

APPENDIX A

Mass Radiography Centre, Kunraghat

The Mass Radiography Centre, Kunraghat was started on 9 December 1944. The work of the centre, the first of its type in India was to be partly experimental, with a view to accumulating data and the training of key personnel. This new venture was sponsored by the consultant radiologist, India Command.

Object: The object of the centre was to prevent the recruitment of men suffering from unsuspected chest trouble, chiefly pulmonary tuberculosis, and to obtain statistics.

Technique: The method employed was that of screen photography, using specially imported American equipment. Heavy radiographic exposures (100 KVP, 50-70 mAS at 36″) were passed through each recruit's chest on to a fluorescent screen, the luminous image on which was photographed by a special camera using 4″ × 5″ film. All recruits were subjected to this procedure. The small pictures were processed immediately, and viewed wet. Full size 15″ × 12″ skiagrams were at once taken of those recruits whose small pictures showed suspicious deviation from the normal. When these skiagrams had been viewed, the indicated clinical procedure including sputum examination and haematology were carried out before the recruit left the centre.

Rate of Operation: Working in the manner just described, it was possible daily to pass or to recommend for rejection about 200 recruits. Generally speaking a batch of 50 recruits had left the centre, with the results of the examination, within 75 minutes of arrival. But when by coincidence large numbers of doubtful cases arrived together, although the individuals could be released within two hours, the results were not always available until the evening of the same day.

Work done at the Centre: Up to 1 March 1945, some 6,000 persons had been X-rayed. Half of these were young Gurkha recruits and half Indian Pioneer Corps labour unit personnel.

Findings: The recruits were placed into three groups: the healthy, including those showing evidence of healed primary tuberculosis; those with non-tuberculous incapacitating chest disease; and finally those judged actually to be tuberculous. The last group included adult-type pulmonary tuberculosis, whether active, doubtfully active, or apparently stable, and other incapacitating tuberculous conditions (chiefly the grosser results of pleural effusion). The actual findings are set out in Table 1, which also indicates the relative superiority of mass radiography over clinical examination alone as a means of detecting tuberculosis.

Extracts from the reports by Major J. Aspin, RAMC, officer commanding the Centre.

TABLE I

Findings of the Mass Radiography Centre, Kunraghat during 1944-45—Labour units and Gurkhas.

	Labour units			Gurkhas		
	Number	Percentage	SE*	Number	Percentage	SE*
Recruits X-rayed at the centre ...	2,941	...	...	3,097	...	...
Recommended for rejection						
Non-tuberculous diseases ...	25	0·85	...	11	0·35	...
Tuberculosis ...	105	3·57	±0·7	30	0·97	±0·4
All causes ...	130	4·42	...	41	1.32	...

* Sampling error $= \sqrt{\frac{pq}{n}}$

It will be seen that nearly 4 per cent. of the labour unit personnel, and 1 per cent. of the Gurkhas, were recommended for rejection as tuberculous. This incidence among the former is three or four times greater than that found in large scale investigations in the Western Hemisphere, and points to an even higher incidence among the agricultural and semi-urban population as a whole. The incidence in the Gurkhas was just as heavy as that found in the Western Hemisphere, although even according to their stated ages, which certainly did not err on the large side, these young hillmen fell into age-groups well below those for maximum incidence of tuberculosis.

It is interesting to speculate on the reason for the different incidence in these two groups, a difference which is statistically significant, amounting as it does to over three times the difference which could have arisen by chance (observed difference=2·6, twice the standard error of the differences $\sqrt{\frac{P1\ q1}{n1} + \frac{P2\ q2}{n2}} = \cdot 77$). Is this difference due entirely to the difference in age-groups or does it point to a somewhat heavier incidence in the plains men ? The answer must await the X-raying of much larger numbers of both groups.

Comments: These findings appear to be of importance to those who have to plan for the future. They are supported by a study of the rather scanty literature on the subject which suggests, though not conclusively, that the incidence of pulmonary tuberculosis amounts to at least 4 per cent. in rural areas, and probably to much more in urban areas. Moreover it is now generally agreed that clinical examination alone will disclose only a small proportion of those among the apparently healthy who are actually tuberculous, and that the remainder can only be discovered by radiography. This point is illustrated by the fact that in the present investigation all the labour unit personnel and half the

Gurkhas had been specially selected and medically examined before they were X-rayed.

In conclusion, if the enlistment of comparatively large numbers of tuberculous men into the Indian Army is to be avoided, there is a convincing case for introducing mass miniature radiography of lungs in the recruiting medical examination.

GURKHA RECRUITS

After an unfortunately late start, some 3,097 recruits were X-rayed. Of these, 0·97 per cent. were discovered to be tuberculous, 0·35 per cent. were found to be suffering from other in capacitating forms of chest diseases, and 5·71 per cent. showed evidence of childhood contact with infectious cases of pulmonary tuberculosis. Since the majority of the recruits was well below the age of maximum incidence for pulmonary tuberculosis, these figures point to the existence of a large pool of infection in the hills.

With regard to the value of mass radiography in Gurkha recruiting centres it is of interest to note that, during 1941-44 when nearly 50,000 recruits were medically examined at Kunraghat, 0·14 per cent. were rejected on account of all forms of respiratory diseases, of which tuberculosis normally forms a part.

It may, therefore, be concluded that mass radiography of the recruits since early December 1944 has disclosed incidence of tuberculosis which previously escaped detection.

The actual findings are presented in Tables II and III.

TABLE II.

Rejections for respiratory diseases (all forms) during 1941-44 at Kunraghat.

Groups	Number	Percentage
Recruits medically examined	49,336	...
Recruits rejected on account of respiratory diseases, all forms	71	0·14

TABLE III.

Findings of Mass Radiography Centre, Kunraghat during 1944-45.

Groups	Number	Percentage
Recruits X-rayed	3,097	...
Evidence of childhood contact with tuberculous infection	177	5·71
Recommended for rejection		
Tuberculosis	30	0·97
Other chest diseases	11	0·35
Total	41	1·32

CHAPTER XXXVII

Surgery in ALFSEA Command

PERSONNEL AND EQUIPMENT

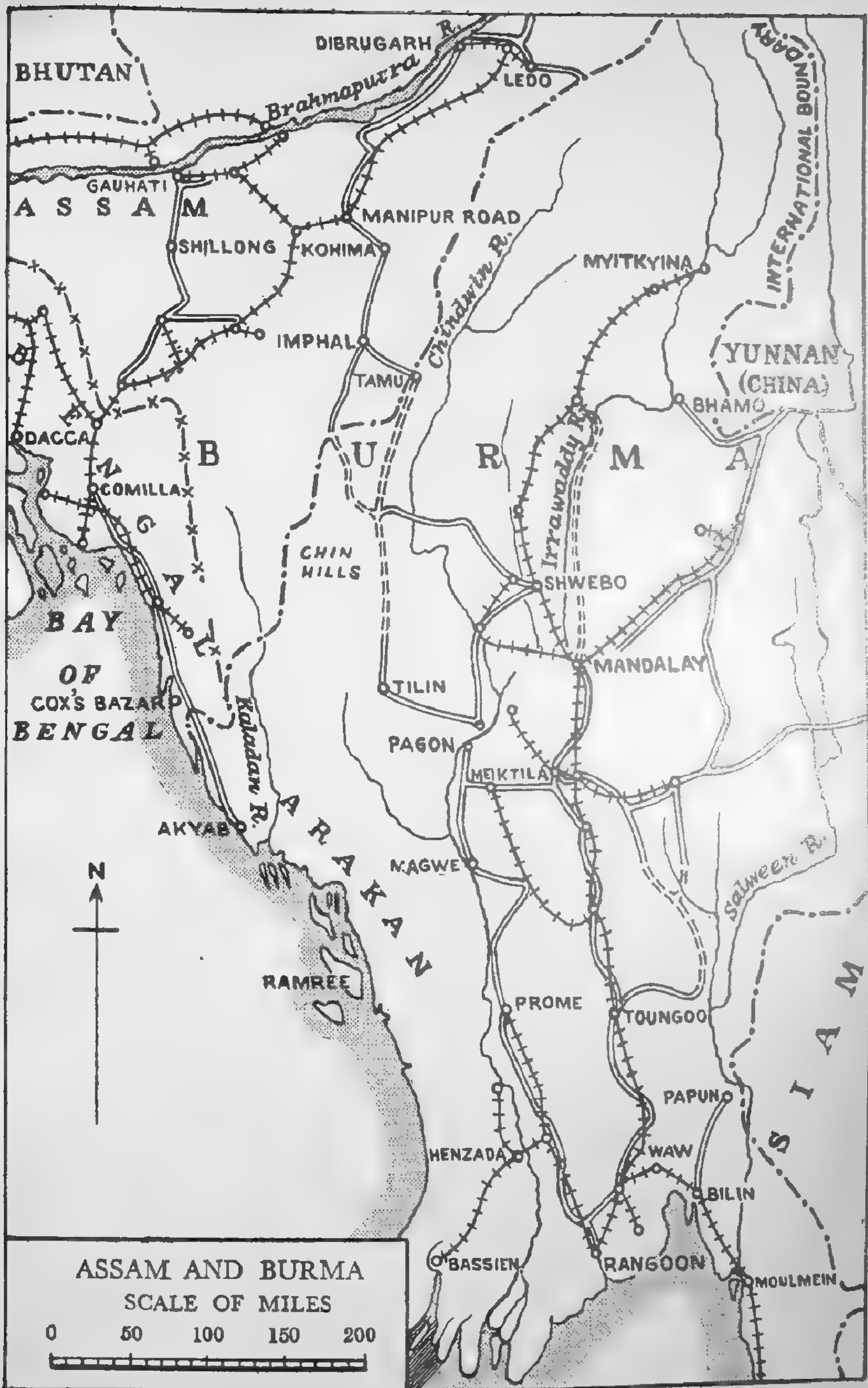
The year 1942 found India quite unprepared to provide surgical cover to an army in the field. The surgical establishment of Indian medical units compared very poorly with that of British units both in personnel and equipment. For instance an Indian CCS had one surgeon, and a 700 bedded hospital carried only two surgeons including the officer-in-charge of the division. Except by attachment of special units there was no ENT surgeon, no ophthalmologist and no radiologist or X-ray set. There was no portable X-ray unit in the MME scale of an IGH. There were many other omissions in the instrument scales. The surgical instruments themselves, mainly of indigenous manufacture, were often of poor design and normally of very poor quality. On top of this, there were such deficiencies in personnel and equipment that even these establishments and scales were seldom complete. The tempo of the normal mechanism of supply and issue in India was not suited to an emergency, and transport was slow and uncertain over the vast distances involved. To make matters worse the War Office were unable to give the necessary help. The demands of other theatres were more urgent and the resources of supply and replacement from the United Kingdom were stretched to the limit.

Despite these difficulties, an efficient surgical service was built up, and in this development, Brigadier Grant Massie, consultant surgeon GHQ from 1942 onwards, played a great part. But in spite of all efforts at improvement, and of help, especially in personnel from the United Kingdom in the later stages of the campaign, the surgeons of the Burma armies had, to the end of the war, to contend with inferior equipment and with deficiencies of both tools and personnel. They lacked many items regarded as essential which were automatically received or quickly supplied on demand by surgeons in other theatres. For instance penicillin-sulphathiazole powder was not available nor insufflators for its use. There were very few proctoscopes—important tools in a land of dysenteric infection. Cystoscopes were in short supply and repairs to them and other instruments took many months. The war establishment of surgeons was never fulfilled. The average of posted strength against war establishment in ALFSEA was about 100 against 130. This entailed many temporary postings to busy units and little or no leave to forward surgeons. Climatic conditions and diseases produced frequent casualties and lowered numbers still further, the average in the field being only 95.

DISPOSITION OF UNITS

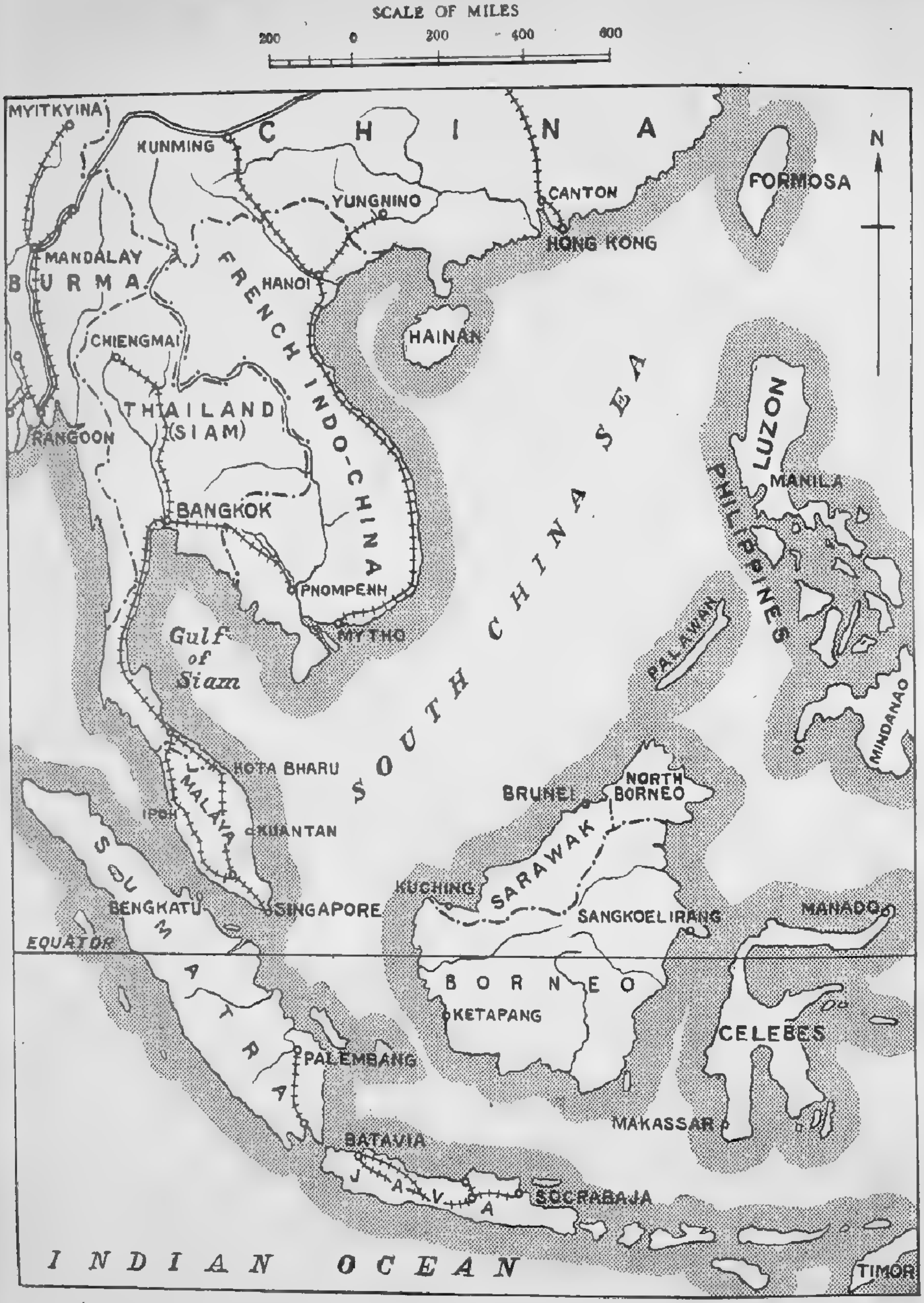
In the early stages of the campaign, for various reasons, India placed the centre of gravity of war surgery far to the west. Poona was the

Abridged report of Brigadier M. F. Nicholls, RAMC, consultant surgeon, ALFSEA.



ASSAM AND BURMA
SCALE OF MILES
0 50 100 150 200

SOUTH EAST ASIA



first great surgical centre to be built up, followed by Secunderabad in the south and Lucknow in the north. Later Bangalore in the south and Ranchi in the east were built but were never used to more than a fraction of their capacity. In these centres in India were the special services such as orthopaedic, maxillo-facial, peripheral nerve injuries and neurosurgery. Forward of this under the control of ALFSEA were the field hospitals, the IGHs and BGHs with eventually, two mobile neurosurgical teams and a number of Indian ophthalmic and ENT units. The policy was to evacuate all serious cases to India but, especially in the Japanese advance in the spring of 1944, when several forward general hospitals had hurriedly to be withdrawn, light cases went too. This journey took many weeks by road, river and rail, and entailed much suffering and wastage due to lack of early treatment. It was not until air evacuation was operating on a large scale in 1944 that the policy began to change. The main axis of fighting through Assam and Burma was north-west to south-east down the valleys and across the passes of the hills. In addition, there was fighting from north to south in northern Assam and Burma on the Ledo—Myitkyina—Bhamo axis, and fighting along the Arakan coast south-east of Chittagong. West of the main axis was an impassable barrier of hills. Except from the Arakan, patients had to travel by road right up to the Brahmaputra Valley in the north where the rail-heads were. From these a metre gauge rail ran south-west to Comilla and Chittagong—a sea port, or west to the bridgeless Brahmaputra over which by river steamer, rail-heads of the railway net-work in India could be reached. Air evacuation of sick and wounded had of course been carried out in Wingate's operations and in the famous 7th Division 'Box' in the Arakan. After complete mastery in the air had been achieved, it became the routine method when forced on a large scale during the siege of Imphal in the spring of 1944. Immediately the grouping of hospital beds round the larger airfields became essential. These were in the main sited along the line Chittagong—Comilla—Agartala and were served by rail and by the port of Chittagong.

Forward units suffered similar difficulties owing to poor communications, until the introduction of light aircraft (L 5s) for evacuation from MDS to CCS. This solved the problem of roadless jungle and to a great extent relegated the lengthy and arduous hand carries, mule carries, etc., to a historical legend of human courage and endurance. Indian mobile surgical units were never sufficient in number. Until 1945, the maximum number was 12 to cover 7 or 8 divisions in action. CCSs were more adequate—there being 8, but it must be emphasised that in the kind of warfare imposed by the terrain more, rather than less, forward surgical cover is needed. West and East African surgical cover is excluded from the above.[1]

[1] *West African Surgery:* The two West African divisions which fought in Burma were surgically self-sufficient. Each division had three graded surgeons in field ambulances, and was supported by three field dressing stations each having a surgeon. There were two general hospitals at advanced base level and one in India to deal with long term cases and with invalids for repatriation. Surgical cover was in the main lavish and in quiet periods particularly so as compared with that of the Indian and British forces. British surgeons were posted to the West African forces by the

PROFESSIONAL COMMUNICATIONS

Surgeons in this theatre were cut off to a very great extent from a knowledge of the experience of what their colleagues in Europe had achieved and learnt. Even when directions were issued from GHQ and later from ALFSEA their delivery to the individual surgeon was delayed and uncertain. All this emphasised the necessity for adequate consultant cover. Prior to the end of 1944, one consultant was responsible for the surgical work in the Eastern Command of India and in the whole field force in Bengal, Assam and Burma, an area of 300,000 square miles with poor communications. To do this adequately was a physical impossibility. Indeed one consultant had a serious breakdown in health as the price of his devotion in attempting it.

In September 1944, a surgical conference was arranged at Secunderabad which was attended by many of the forward surgeons. This was most valuable. The air was cleared, ideas were crystallised and standard modern methods preached and agreed to. Unfortunately it was the last conference of its kind. The tempo of war quickened, distances lengthened and transport became more difficult, giving no further opportunity for a large gathering of surgeons.

In spite of all these disadvantages excellent work was done by the forward surgeons, and it is sad that only a few isolated individual records exist to prove it. One surgeon working in desperately bad conditions in the Arakan performed a series of 50 operations on penetrating wounds of the abdomen with 19 deaths, a recovery rate of 62 per cent. This in view of the difficulties of collection of wounded in that terrain in that climate at that time is an amazing sequence. For their work at this time some surgeons received awards for bravery, skill and endurance; many more deserved them.

SITUATION IN JANUARY 1945

Operational Background: Owing to the relentless pursuit of the Japanese defeated at Imphal and the continuous pressure put on them

War Office and were not at the disposal of other commands. The West African commanders were naturally jealous of their rights and insisted that their establishments were left intact. This led to the anomalous situation that surgeons of the West African field units were idle and dissatisfied at a time when surgeons were badly needed to treat the Indian and British casualties. The need for officers experienced in dealing with Africans was understood, but by no means all the surgical reinforcements supplied were in this category. In other circumstances it would have been possible to employ the West African surplus by transfers on temporary duty to busy units, but the difficulty and time taken in moving even one individual in this theatre often made this expedient impracticable. The standard of West African surgery was good, but the field ambulance surgeons by virtue of their attachment to brigades were apt to be professionally isolated. This was a noticeable disadvantage especially as many of them were young and inexperienced.

The West Africans brought with them three endemic surgical conditions, bone yaws, guinea worm and schistosomiasis of the bladder. All were common causes of invalidment.

East African Surgery: The East African division's surgical cover was provided by a field surgical unit, a CCS and two East African general hospitals of 1,000 beds, one at advanced base level and one in India. The same difficulties obtained as with West African surgeons, though to a lesser extent. The standard of surgery in East African hospitals was excellent.

throughout the monsoon the Fourteenth Army (XXXIII Indian Corps and IV Indian Corps) had at the beginning of the year finally emerged from the jungle hills and fever-haunted valleys into the Irrawaddy plain and were preparing for the final assault across that river. In the north the 36th British Division was advancing on the right flank of the American and Chinese components of North Combat Area Command southwards from Myitkyina down the railway corridor. On the Arakan the XV Indian Corps was advancing down the coast through the valleys of the Kaladan and Kalapanzin rivers towards Foul Point and at the same time preparing for the imminent assault on Akyab.

Disposition of Units and Lines of Evacuation: The Fourteenth Army had at that time only five mobile surgical units. These had been barely sufficient for the preliminary fighting and were obviously inadequate for the assault on the line of the Irrawaddy where the Japanese were to make their most determined stand. They were also supported by five Indian CCSs.

The 36th British Division had one mobile surgical unit and one British CCS.

XV Indian Corps in view of its combined operational role had no less than five mobile surgical units but these were in process of being reduced by two in favour of the Fourteenth Army. They had the support of three CCSs, while the 82nd West African Division had its own surgical cover with surgeons in each field ambulance and one in each of the West African field dressing stations.

The general plan of evacuation was that L5s brought casualties from field ambulances back to the CCSs which were located near both L5 and Dakota strips. After preliminary treatment, casualties were evacuated to advanced base hospital level where more definitive surgery was undertaken. As a result of this the more forward hospitals in the Imphal plain in the north and at and near Cox's Bazaar in the Arakan were by-passed and casualties from these fronts were evacuated direct to Comilla. Thence they went by ambulance train to the north where the hospital centres were located—Agartala, Dacca, or south to Chittagong and thence by hospital ship to Calcutta and Madras. In addition, special cases were evacuated by air from Comilla to Calcutta but only a small fraction of the casualties were carried by this route.

In the northern area light and heavy aircraft carried casualties northwards to advanced base hospitals around Dibrugarh. From there they were carried to Gauhati by ambulance train and then ferried over the river to the Indian railway system.

Neurosurgical cases were dealt with in ALFSEA by Nos. 2 and 3 Neurosurgical Units. At this period No. 2 Neurosurgical Unit was at Manipur Road covering both the 36th British Division and the northern divisions of the Fourteenth Army. It got little work from either and was soon moved forward to a CCS in close support of the Fourteenth Army. No. 3 Neurosurgical Unit was situated at Comilla and to it the vast majority of penetrating head wounds were flown direct from the CCSs of the Fourteenth Army and XV Indian Corps.

The further evacuation of these cases was less satisfactory.

Eye cases were evacuated by air to Comilla where the ophthalmic department detached from No. 14 BGH was working in conjunction with No. 3 Mobile Neurosurgical Unit.

Maxillo-facial cases could not be specially dealt with in ALFSEA. The nearest centre for British troops was at Ranchi and for Indian troops at Lucknow, both very inaccessible. Afterwards No. 3 Maxillo-facial Unit was moved forward to Comilla to work in conjunction with the other members of the trinity.

There was no special set up for chest wounds or for wounds of blood vessels.

Methods of Treatment: Alterations in methods of treatment of wounded was synchronous with and closely related to alterations in the methods of evacuation which became the rule at about that time. Penicillin had only just come into full supply at the end of the year, although some stocks had been received in the autumn.

In October 1944, a penicillin research and training centre had been set up by the consultant surgeon, Fourteenth Army at an IGH at Comilla and there surgeons and nursing officers from ALFSEA were trained in the technique of its use, which then became a matter of general routine. At the same time the experiences in delayed closure of wounds was brought to the knowledge of the surgeons, and this technique, made possible by improved evacuation and by modification of the holding policy in ALFSEA hospitals and promulgated by directives and personal encouragement, became the universal practice at advanced base hospital level.

Holding Policy: The policy in force was a 'three months' one, i.e., that any patient who was not considered likely to be fit for duty within three months was to be evacuated to India as soon as possible. This policy had to be altered to allow for delayed closure and it was then laid down that long term cases should be evacuated to India as soon as possible after their preliminary treatment had been completed. This necessitated a stay in advanced base hospitals for a period varying from 10-14 days to 8-12 weeks (as in the case of GSW of femur).

Consultant and Advisory Personnel: Brigadier John Bruce took over the surgical supervision of the Eastern Command, India, and the army in the field from Colonel John Gardham who returned to the United Kingdom in the early part of 1944. It was not, however, until relieved in the Eastern Command by Brigadier P. Wiles in late October that he was also able to devote himself exclusively to the Fourteenth Army. Brigadier M. F. Nicholls arrived at the end of November as consultant surgeon to ALFSEA. It quickly became apparent that the consultant to the Fourteenth Army had a full job as such and that it was difficult for him to visit the XV Indian Corps in the Arakan. The task of consultant surgeon to ALFSEA—that of liaison back with India and liaison forward with Burma—made it impossible to give adequate supervision to the hospitals in the freshly created Line of Communication Command. There were some 40 of them scattered over an area roughly the size of Great Britain with practically no lateral

communications. Accordingly the DMS, ALFSEA, applied to GHQ and the War Office for a consultant surgeon for the Line of Communication Command. Already Brigadier, P. Wiles, as consultant surgeon in the Eastern Command, India, had a close liaison with the consultant surgeon ALFSEA in the treatment of ALFSEA casualties and his appointment to the Line of Communication Command early in the year was very opportune.

At the beginning of the year, there were no other specialist advisers but in March and April 1945 five officers joined ALFSEA Headquarters.

OPERATIONAL BACKGROUND AFTER JANUARY 1945

It is convenient to divide the campaign operationally into phases. First from January to April 1945, the advance to the Irrawaddy and the establishment of bridgeheads across it culminating in the battle which achieved the crossing, the capture of Mandalay and Meiktila and the junction of the Fourteenth Army with the 36th British Division of Northern Combat Area Command in the north. Second in April 1945, the pursuit of the Japanese from Mandalay to Rangoon and the junction with the XV Indian Corps who had come into that city by a combined assault. During the first phase, the XV Indian Corps had advanced down the coast of the Arakan by a series of sea-borne assaults of varying size capturing the port of Akyab and the island of Ramree and finally achieving, almost unopposed, the capture of Rangoon on 1 May 1945. Thirdly, the mopping up of the broken Japanese Army between May 1945 and the surrender in August 1945. Fourthly, the far flung deployment of forces necessary for the re-occupation of enemy held Allied and other territories.

First Phase: The pattern of evacuation of wounded remained essentially the same as was established by 1 January 1945. It is important to realise that in this period the fighting troops were to a great extent both reinforced and rationed by air. The reinforcement camps were situated at Comilla and it was by aircraft returning to Comilla after taking forward reinforcements that the casualties returned. Comilla, therefore, became the big surgical centre, and No. 74 IGH(C)—1,000 beds, No. 92 IGH(C)—700 beds and No. 14 BGH—1,200 beds were the main hospitals involved surgically. Patients were also passed directly or from these hospitals to Dacca and Agartala by ambulance train. Dacca, which had been reinforced by several orthopaedic surgeons, dealt in particular with major fractures, especially femurs. The general plan gave surgeons the chance of giving a war wound its optimum treatment at the optimum time. Some difficulty was experienced in getting patients quickly from field ambulances to CCSs owing to the fact that light aircraft could not operate in the hours of darkness. Similar delay was also experienced in the Arakan coastal region in which XV Indian Corps fought, owing to the delays inherent in river and sea transport and to isolation of units. On the whole, however, casualties received their forward and hospital surgery at the best period and a rhythm of work was achieved and maintained with excellent results.

During this period the 'Corps Medical Centre' came into prominence. It consisted ideally of two CCSs reinforced when possible by mobile surgical units, one IMFTU (700 beds for light cases) and various special units.

Second Phase: This fortunately resulted in comparatively few casualties, but the pursuit was so rapid that difficulty was met in keeping surgical units close enough to the fighting, which constantly advanced from the light air-fields beyond the range of light aircraft. From CCS backwards too, a new difficulty in evacuation arose. As the Fourteenth Army pushed far south, Akyab and Ramree became the main air supply bases and patients were brought to these places by returning aircraft. It was not often possible for them to continue their journey to Comilla on the same day, and the islands were so poor in suitable sites, that hospital accommodation could only be provided for patients in transit and not for their treatment. These factors spoilt the rhythm of evacuation and had an adverse effect on the success of delayed primary closure procedures.

Third Phase: The mopping up operations conducted by the Twelfth Army, formed from elements of the Fourteenth Army, resulted in few casualties among Allied troops as compared with the Japanese. Owing to the monsoon, roads were almost impassable (railways had been cut) and flying conditions were very poor.

Until No. 38 BGH and No. 58 IGH opened in Rangoon early in June 1945, the preliminary surgery was done by widely scattered forward units where the casualties reached by ambulance vehicles. They were evacuated further by air to Akyab for onward transmission to Comilla. From the southern area ambulances brought casualties to a CCS at Rangoon whence they were evacuated by sea to Chittagong.

The irregularities and delays of these routes again produced an adverse effect on the surgical results which improved only when adequate hospital accommodation could be provided at Rangoon.

Fourth Phase: The Japanese surrender gave rise to a new surgical problem, that of providing cover to large and small forces isolated by many hundreds of miles of sea or air from their bases at Rangoon and, later Singapore. To these outposts the advanced base hospitals of Eastern Bengal then moved. Hong Kong, French Indo-China, Java, Sumatra, Siam, Borneo and Celebes were occupied by Allied forces and in three of them at least fighting with considerable casualties broke out. The immediate problem was solved by the provision of surgical units, CCSs and *ad hoc* surgical teams, but communications and distances necessitated the provision of hospital cover in each locality. From these, sea and increasingly precarious air evacuation brought the patients to Singapore, which rapidly became an extremely busy surgical centre. Once again the timing of evacuation, especially with urgent cases such as neuro surgical ones, fell short of perfection as did the results.

RESULTS OF SURGICAL TREATMENT

Mortality: The price in casualties for the period January to August 1945 was ;

Killed	4,869
Wounded	16,517
Missing	555
Total	21,941

Of the wounded, figures show that between 95 per cent. and 96 per cent. of those who reached a forward medical unit survived to be evacuated. This percentage includes a proportion of trivial cases.

The results of forward surgery in the Fourteenth Army from January to May 1945 are given in Table I.

TABLE I

Results of forward surgery—Fourteenth Army—January to May 1945.

Region	Admissions	Deaths	Case fatality rate per cent.	Percentage survival
Skull				
(a) Dura pen	201	14	6·97	93·03
(b) Non pen	306	4	1·31	98·69
Maxillo-facial	203	12	5·91	94·09
Thoracic	329	21	6·38	93·62
Thoraco-abdominal ...	65	34	52·31	47·69
Abdominal				
(a) Visceral	332	123	37·05	62·95
(b) Retroperitoneal ...	59	12	20·34	79·66
Buttock				
(a) With bone injury ...	39	...	...	100·00
(b) Visceral injury ...	46	10	21·74	78·26
Fractures				
Spine (paraplegia) ...	40	5	12·50	87·50
Spine (no paraplegia) ...	15	...	...	100·00
Femur	285	19	6·67	93·33
Leg	310	11	3·55	96·45
Foot	142	3	2·11	97·89
Humerus	287	5	1·74	98·26
Forearm	307	3	0·98	99·02
Hand and wrist ...	586	2	0·34	99·66
Joints				
Hip	3	...	...	100·00
Knee	177	...	...	100·00
Ankle	41	1	2·44	97·56
Shoulder	51	1	1·96	98·04
Elbow	61	...	...	100·00
Flesh wounds				
Minor	2,111	2	0·09	99·91
Major	2,084	9	0·43	99·57
Vascular ligatures ...	155	12	7·74	92·26
Burns—major	103	9	8·74	91·26
Anaerobic infections				
Myositis	61	20	32·79	67·21
Cellulitis	51	1	1·96	98·04
Total	8,450	333	3·94	96·06

Table I shows that of 8,450 patients operated on by forward surgeons in that army, 96·06 per cent. were evacuated alive. It is interesting to compare the mortality rate of 3·94 per cent. after operation with that of 7 per cent. estimated by the consultant surgeon, Allied Force Headquarters[2] and 5·1 per cent. published by British Liberation Army (BLA).

It is probable that the collection and evacuation of the recently wounded in Italy and in Burma were comparable in difficulties and delays to a large extent absent in North Western Europe.

Complete returns from the surgeons working with XV Indian Corps in the Arakan were not received as the units were often isolated and communications with them difficult. This was particularly true of the units of the 82nd West African Division in which a surgeon was carried on the strength of each field ambulance. Statistical returns were neither the only nor the most important victims of these geographical and tactical disadvantages. Scrutiny of reports shows that on the whole the results were not quite so good as those of the Fourteenth Army surgeons. The surgeons were man for man equally good but the poor conditions of work and the difficulties of both forward and rear evacuation could not entirely be overcome.

The mortality among casualties who reached base hospital appears to have been not more than 0·4 per cent. in the first three months after wounding.

RESULTS OF TECHNIQUE

Delayed Closure: During this period the lessons in technique learnt from other theatres and also the eastern theatre were universally applied and the 'two stage' treatment of thorough excision and early closure became the rule. Most of the surgeons were novices in the method (some were hard to convince of its value) but the results were striking.

An investigation on the results of this method of treatment was undertaken in April 1945, by Brigadier P. Wiles, then consultant surgeon, Line of Communication Command. One thousand random flesh wounds so treated were assessed fourteen days after closure by the following high standards :—

100 per cent. success	=	Dry linear scar.
90 per cent. success	=	Minimal granulation or slight moistening of stitches.
50 per cent. success	=	Gaping of wound up to 50 per cent. of its length, no gross infection, no deep sinus.

Failures = All cases worse than above.

The results were as follows :—

Success	(90 per cent. to 100 per cent.)	...	58 per cent.
	(50 per cent. to 90 per cent.)	...	27 per cent.
Failures	... ...	...	15 per cent.

[2] Surgery in Italy by Brigadier Harold Edwards, CBE, p. 4 para 1.

These figures include both delayed and secondary closures. There is evidence that many of the partial successes became complete in a further 14 days.

These results fall short of what was achieved in Italy but may be regarded as a great advance on anything done previously here. It is unfortunate that, owing to a delay in the receipt of instructions, the hospitals which did the bulk of the work at Comilla contributed to only a small degree to the report which is, therefore, not strictly a representative one. Seven hundred of the case reports came from the Dacca group of hospitals at which patients arrived by ambulance train after considerable delay. Only 21 per cent. of cases were sutured within six days of wounding—the optimum period, while 55 per cent. could not be operated on until 14 days or more after wounding. The latter must nearly all have been secondary sutures, and the record of 85 per cent. complete and partial success is all the more impressive. It certainly represented an enormous saving in manpower. As in other theatres early skin grafting was used in place of or to supplement suture. Split skin graft cutting was not easy owing to the shortage in Indian hospitals of suitable knives or razors and of operating room attendants skilled in setting them. Where such difficulties were not surmountable 'pinch grafts' were applied with excellent results. Some surgeons used them from choice. The results of closure as applied to compound fractures were equally encouraging.

PENICILLIN

It was not until October-November 1944, that penicillin was available to ALFSEA in significant quantity. Already, in August 1944, a penicillin research centre had been set up by Brigader Bruce at No. 74 IGH(C), Comilla. This was a hospital nominally of 1,000 beds (700 Indian and 300 British) which received casualties from forward areas from and after the siege of Imphal. In consequence it was very busy and its bed state varied from 1,500 to 2,000. Housed in *bashas* with open sides with large tanks of stagnant water dotted about the area; dusty in dry weather and hot, humid and muddy in the drenching monsoon, it typified the hospitals of a period when no better sites were available. There a ward of some 50-60 beds was handed over to Lieut.-Colonel J. A. Baty, OBE, an officer of considerable experience in forward surgery in this theatre. An EPIP tent, as far as possible fly proofed, was erected nearby as a dressing room. It was felt that this adherence to the field conditions which generally obtained in ALFSEA would make Baty's findings generally applicable. Selected cases were treated and investigated there and courses of instruction were given to surgeons and nursing sisters. By January 1945, at least one surgeon in each of the hospitals had attended the course, and penicillin was widely used in the treatment of war wounds.

Calcium penicillin-sulphathiazole powder was never available in this theatre except to neuro-surgical units to whom it was specially sent from the United Kingdom and who, alone, possessed insufflators. The method of 'frosting' the excised wound, considered to be of proved value in Italy, could never be employed here.

In the advanced base hospitals penicillin was widely but not universally used as an adjunct to wound suture. Baty found that instillation by tube or tubes into the wound itself carried undue risks of infection in the conditions in which he was working, and this opinion was general. Intramuscular drips were not popular and were seldom successfully used there, the standard method being intermittent intramuscular injections of 15,000 units three hourly—the dose being concentrated into 1 cc.

There is no doubt that intramuscular penicillin played a great part in the improvement in the results but there were certain difficulties peculiar to this theatre. Of a series of wounds investigated at an advanced base hospital some 30 per cent. were found at the first dressing to be infected with penicillin resistant organisms. The most consistent of these was an atypical *Bacillus coli*, a resident of the dust, but *B. proteus* and *B. pyocyaneus* appeared with alarming frequency and resistant *Staphylococci* were often associated with the *B. coli*. As has been found elsewhere, the presence of these organisms was not necessarily a contra-indication to suture, and most wounds were assessed on their clinical appearances without benefit of bacteriology. At the same time these invasions, which did not appear to be preventable, produced a quota of acute and chronic sepsis not susceptible to treatment by penicillin.

Brigadier P. Wiles in his investigation into the 1,000 cases of wound closure brought some interesting facts to light. Systemic penicillin was only used in 23 per cent. of cases, and combined with local instillations in 4 per cent. Local penicillin alone was given to 11 per cent. To quote his report :—

> " It is striking that the results, then considered without regard to date of suture, are practically identical whatever method was used, systemic, local or no penicillin. When these results, however, are analysed according to date of suture it would seem that the cases treated with systemic penicillin produce rather fewer complete successes and rather more partial successes than when no penicillin is used. This is possibly because penicillin is used for the worst cases, the results of these being improved thereby from failures to partial successes."

If these figures seem to give doubtful praise to the value of penicillin, they are offset by the general conviction of the surgeons that results have been achieved which would have been impossible without its help; and that they had succeeded in methods of treatment which, without the confidence given by penicillin, they would not have been bold enough to use.

Penicillin was given systemically to most cases of abdominal wounds in the later stages of the campaign.

CHEMOTHERAPY

The practice of dusting wounds after excision with sulphanilamide powder was largely discontinued at the start of this campaign. Earlier experience had shown that it frequently embarrassed the operator at the second stage without preventing infection of the

wound. Sulphanilamide, selected for its high solubility, was given by mouth to all wounded men as a routine measure. The maintenance of regular dosage in the course of evacuation was ensured by the administration of the drug at fixed hours twice daily. The hours selected were 0700 hours and 1900 hours, 4 g. being given on each occasion. Very stern warnings were issued of the grave danger of anuria in this climate and a large fluid intake was insisted on. The result was excellent, Brigadier Bruce being able to say of the Fourteenth Army—"There is no report of a single case of anuria from this cause (sulphanilamide) alone during the campaign."

For gas-gangrene sulphathiazole was thought to be more efficacious, and this was also the drug of choice for all wounded men after they had reached the advanced base hospitals where complete supervision and control of fluids became possible. It was generally agreed at this level that, in view of the high proportion of penicillin resistant infection, the routine administration of sulphathiazole was necessary and beneficial. The neurosurgeons preferred sulphamethazine.

In this theatre sensitisation dermatitis of the skin following surface application of sulphanilamide was an unusual menace, owing to exposure to the sun. Instructions had to be issued from time to time forbidding its use on superficial lesions, but exception was made in the cases of severe burns of the body surface.

GAS-GANGRENE

The incidence of gas-gangrene increased especially in the Irrawaddy bridgehead battles. It is possible that the emergence of the army from the jungle into the cultivated plains around Mandalay was responsible.

Percentages from the Fourteenth Army and North West Europe are comparable.

Diseases	Percentage of forward operations		Survival percentage	
	BLA	Fourteenth Army	BLA	Fourteenth Army
Anaerobic myositis ...	0·5-0·6	0·7-0·8	77	67
Anaerobic cellulitis ...	0·1	0·6*	90	98

*It seems probable that some Fourteenth Army surgeons recorded trivial or fallacious cases of anaerobic cellulitis. The negligible mortality rate of this condition can hardly otherwise be explained.

Apart from this discrepancy the figures correspond closely. The incidence in the Italian front appears to have been lower and not to have increased with a move to more cultivated country.

As in other theatres penicillin seems to have been the most useful adjunct to radical surgery. Polyvalent antiserum was used for established cases and where the nature of the wound (for example injury to the main vessel or gross muscle damage) made gas-gangrene likely. In either event large therapeutic doses of 50,000 units and upwards were used. The administration of a small prophylactic dose (9,000 units) as a routine measure for all wounds was discouraged.

TETANUS

The consultant surgeon, Fourteenth Army does not mention tetanus in his report, and it may be assumed that this complication did not arise to any serious degree at forward levels. Unfortunately the disease was not, until recently, notifiable and exact figures cannot be quoted. From August 1944 to June 1945, between seven and eight thousand surgical cases (of which the majority were battle casualties) were treated in No. 74 IGH(C). Of these only six developed tetanus.

As pointed out by Baty, in the six months February to July 1944, before the introduction of penicillin and early wound closure, at least six cases developed among many fewer casualties—indicating that modern methods do not enhance the risk of this complication. Of the six more later cases, two died. All were treated with antitetanic serum intravenously, penicillin in large doses and sedatives.

It will be seen that no new technique of management of this disease, the course of which is apparently not influenced by penicillin, has emerged.

RESUSCITATION

The peculiar difficulties of maintaining a transfusion service in this theatre were magnificently overcome by the efforts of GHQ in the early stages of the campaign and in particular by the officer commanding of No. 2 Base Transfusion Unit, (Lieut.-Colonel Hugh Ellis, RAMC) later adviser in transfusion to DMS, ALFSEA.

The pattern of the transfusion was as follows :—

No. 2 Base Transfusion Unit was at Dehra Dun and No. 2 Advanced Base Transfusion Unit at Calcutta, both units being under the command of GHQ with six (in the closing stages of the campaign seven) field transfusion units in the field under the command of ALFSEA.

At a glance there are three remarkable features of this arrangement; first, the enormous distances involved between the base unit, the advanced base unit and the forward troops respectively; second, the paucity of field transfusion units; and third, the divided control. The first point is to be explained by the difficulty of finding centres in India with access to sufficient static troops to provide a panel of suitable and willing donors, with supplies of water and electricity adequate for a base unit, housed reasonably and in a reasonable climate. Forward of Calcutta no such place could be found until Rangoon and Singapore

were reached. This factor increased the actual shortage of field transfusion units, for these had in the main to be employed as distributing centres and could do little expert resuscitation, their proper function—a grave loss to the forward surgeons. Blood could only be stored for more than a few hours in the very few CCSs and mobile surgical units which had refrigerators—the ice boxes supplied being in the main defective and the supply of ice uncertain. Blood was, therefore, only sent on demand. In spite of all these difficulties, in the first three months of 1945, it was supplied at the rate of 20 pints per 100 casualties, and the field transfusion units were able to report that they had met every demand made on them from forward units. There is reason to believe, however, that without field transfusion units working closely with them, and anticipating difficulties of supply, forward surgeons made smaller demands for blood than they otherwise would—to the detriment of some of their patients.

Transfusion fluids were distributed almost entirely by aircraft to corps medical centres by Dakotas, and from there to forward units by L 5s. The latter could not operate by night, the busiest time for surgeons forward of the corps centres, and this was a great handicap. Plasma, both dry and wet, was in adequate supply. Wet, on account of its smaller bulk, was chosen for combined operations.

The consultant surgeon, Fourteenth Army in his summary of the campaign stressed the following points :—

(a) The lack of field transfusion units functioning as resuscitation teams.
(b) The mistake of holding cases too long at ADS level for resuscitation, with the danger of subsequent relapse into 'irreversible' shock before they could be brought to the surgeon.
(c) The relative infrequency of transfusion complications, notably despite the climate, anuria. Dried plasma, oddly, produced a number of rigors.
(d) The superiority of saline over hot sweet tea (which he describes as a sickening concoction) in the tropics. He describes the administration of salted water as 'perhaps the most important single resuscitation measure at the ADS'.

The need for crystalloids, especially saline, was very great in this theatre, and it is considered that not all the surgeons were alive to this increased need. Lieut.-Colonel H. Ellis received the impression during a tour of forward units in April 1945, that patients were not receiving adequate quantities of crystalloids and recommended that more rigid measurement and chloride testing of urine should be enforced. But, as he stated "owing to shortage of personnel it has unfortunately been impossible for the transfusion service to collect sufficient reliable resuscitation data in this theatre to enable it to make any authoritative statement. It has been noted, however, that during the hot weather a higher mortality rate (in abdominal cases) was experienced by certain medical units where cases received six or less pints of crystalloid solutions per day than in those who gave ten or more pints per day. It is also thought that post-operative treatment could have been improved if field transfusion unit personnel had been able to assist in it to a larger

degree". Both statements were, in the opinion of the consultant surgeon ALFSEA, incontrovertible.

After V. E. day the shock research team from Italy was offered to ALFSEA who gladly accepted it. The fall of Japan, however, happened too soon for the team to arrive. It seems, on the face of it, a pity that the resources of India and the United Kingdom were not equal to provide a field team for Burma to do research in shock and allied conditions. An unique opportunity to study these problems in tropical conditions had been lost. In no other theatre was skilled resuscitation more needed but here alone was the scale of field transfusion units markedly deficient.

REHABILITATION

Convalescent Depots: The importance of rehabilitation increases conversely with reserves of manpower. It is possibly due to this factor that the Army in India was so ill provided with rehabilitation facilities. The Indian convalescent depot had but a meagre establishment suitable to its restricted role. An order forbade these units to retain patients for more than three weeks and no patient needing medical attention (e.g., wearing a plaster, however, small) was allowed to be transferred to them. Few of the physical training instructors had any knowledge of remedial work and no masseurs or masseuses were on the establishment. The unit was uneconomical having only 500 beds. In addition, the convalescent depots attached to ALFSEA were seldom up to strength in key personnel.

These disadvantages were keenly felt when attempts were made in ALFSEA to use the units tactically to save hospital beds and to save the wastage of manpower incurred by the evacuation of short term cases over long distances. An added difficulty was the scarcity of locations climatically suitable for convalescence anywhere near the fighting area. There were convalescent depots at Comilla and Dacca but for most of the year the climate of the Eastern Bengal plain is most unpleasant. Hill stations such as Shillong were used but it took days of uncomfortable travel from the busy hospitals to reach them. In fact, for one reason or another, convalescent depots played a very minor part in the surgical treatment of the casualties.

In the end, when movements of units had to be severely restricted owing to lack of transport, a certain number of beds were set aside in the IMFTUs to hold light and convalescent cases at the corps medical centres. These units had of course no special facilities for rehabilitation.

Physiotherapy: Although an IGH had an establishment for one or two masseurs, trained personnel were scarce, and in January 1945, there were in fact few physiotherapists in ALFSEA. The importance of early movements, especially of fingers and toes, was recognised and overworked medical officers and nursing sisters did their best to enforce them but the results were unsatisfactory. There was an urgent need for physiotherapists with advanced base hospitals, and a reasonable case for putting some as far forward as corps medical centre. The latter

was never achieved, but a number of masseuses were obtained from GHQ in April 1945, and posted to the advanced base hospitals where they did invaluable work with a minimum of apparatus. The number available varied but was never sufficient for the needs.

Specialists in Physical Medicine: The consultant in physical medicine to the War Office, Brigadier Frank Howett visited ALFSEA in May 1945, and advised (among many other reforms) the posting of specialists to supervise rehabilitation. Unfortunately this could not be implemented until at a late stage when the need had greatly decreased. There is no doubt that advice and control in this branch, earlier in the campaign, would have made for greater efficiency.

ABDOMINAL WOUNDS

No especial lessons were learnt in this theatre about the surgery of wounds of the abdomen. The results in the Fourteenth Army were of average success. It would appear, however, from such figures as are available that the results obtained by surgeons in XV Indian Corps were less satisfactory and lower than the over-all survival rate. The deployment of isolated columns in a difficult terrain has already been cited to account for the comparative lack of success in this area but there is another important factor—the West African patient. A large proportion of casualties from the Arakan were from one or other of the two West African divisions and there is evidence that Africans do not recover so readily from abdominal wounds as do the British. The same is true, though to a lesser extent, of many Indian troops and is probably due to difficulties in after treatment rather than to any inherent constitutional weakness.

In general it would be natural to suppose that dehydration would be a major problem in abdominal cases treated in tropical heat. The adviser in transfusion was of the opinion that crystalloids were not, on the whole, given in adequate quantity. On the other hand some forward surgeons contended that results would have been better had whole blood been more readily available. This, like many individual and local impressions, is discounted by the weight of evidence from this and other theatres. Rapid collapse from a severely bleeding abdominal wound makes a greater impression on the memory than a gradual post-operative death, and often cannot be prevented by even the most resolute surgeon.

The whole situation emphasises the loss suffered from the shortage of field transfusion units. The judgment and technique of an experienced transfusion officer is never more needed than with a difficult abdominal case especially when the surgical team is busy in the theatre.

The following facts and figures were taken from an analysis of 300 cases of abdominal wounds, including thoraco-abdominal wounds, operated on by forward surgeons from all parts of the front.

The average time, after wounding, of admission to a unit with a surgical team was eleven hours, although in quiet periods many arrived within five hours.

Before evacuation from a forward unit 150 died—a 50 per cent. mortality. Nearly half of these died within 24 hours and nearly five-sixths within 48 hours of wounding. About half of the deaths were ascribed to haemorrhage and shock, and no doubt many were so severely wounded that no surgery could save them.

The types of lesion found to be most fatal were thoraco-abdominal wounds, abdominal wounds with associated injuries such as compound fractures and multiple injuries which included either the small or large intestine. Where the bowel alone was damaged the mortality was small but wounds of the small intestine were nearly twice as lethal as those of the large. Uncomplicated injury of the liver, kidney or spleen carried a very low risk of life.

ORTHOPAEDIC SURGERY AND FRACTURES

Prior to 1945, expert orthopaedic surgery was not available in ALFSEA. India had a number of flourishing, well equipped and well staffed orthopaedic centres attached to selected base general hospitals. The time involved in getting casualties to these did not allow modern methods of early wound closure to be practised and expert treatment, especially of fractured femurs was obviously needed further forward. This need was partly met by Eastern Command, India (to which Brigadier P. Wiles was consultant surgeon) who pushed forward two orthopaedic surgeons from Ranchi to 17 BGH at Dacca where an advanced fracture centre for British troops was set up in January 1945. More was needed if the general standard, especially in Indian hospitals, was to be raised, and, in April/May 1945 two orthopaedic surgeons were obtained from India to be attached to each of the two main hospital centres adumbrated at Rangoon and Singapore, and were posted to suitable hospitals for this purpose. Once again the rapid collapse of the Japanese prevented the treatment of any large number of battle casualties by them, but there were many road accidents and their employment as regional orthopaedic experts was fully justified. Prior to their arrival, orthopaedic conditions such as internal derangement of knee joints had all to be evacuated to India. Detailed reports of results in delayed closure with cases of compound fracture of femurs by missiles, prepared by Lieut.-Colonel H. I. Maister, RAMC, of No. 17 BGH Dacca, and Lieut.-Colonel J. A. Baty, OBE, RAMC, of the penicillin centre at No. 74 IGH(C) Comilla have been referred to earlier.[3]

VASCULAR SURGERY

There was no special centre for the treament of vascular injuries in ALFSEA. The cases were in the main long term ones and were

[3] See Chapter XXXIII, page 706.

evacuated to India. A few urgently leaking aneurysms were dealt with by various surgeons. The results of lesions of the main arteries were similar to those described from other theatres. Similar precautions were taken (e.g., splitting of fascia, antigas-gangrene serum and blood transfusion) with similar results. There were no complications peculiar to this theatre.

THORACIC SURGERY

No thoracic surgeon ever served in ALFSEA. Later cases were treated in whatever unit or hospital they came to. Long term cases were evacuated to India.

Thoraco-abdominal wounds showed the usual high early mortality —over 52 per cent. in forward units of the Fourteenth Army, but of thoracic wounds that came to medical units, over 93 per cent. survived to be evacuated further back.

Owing to the possibility of flying at high altitudes chest cases were held at CCS level longer than the average and were not evacuated until fairly stable. Usually the medical specialist of the CCS was responsible for aspiration and general management of the cases.

The incidence of empyema does not appear to have been high. At hospital level very few cases were seen. There were remarkably few in which a foreign body of any size was retained—in fact Brigadier M.F. Nicholls, consultant surgeon, ALFSEA had no personal knowledge of an operation for the removal of a foreign body having been performed in ALFSEA during his service with that command. It is possible that many such cases did not survive to reach the forward units, and that some are included in the 6 per cent. who died after preliminary surgery.

As with joints there was a tendency to rely on aspiration without subsequent penicillin instillation unless infection was already present.

NEUROSURGERY

Neurosurgical facilities in ALFSEA consisted of two mobile neurosurgical units, Nos. 2 and 3. Of these, No. 2 Mobile Neurosurgical Unit was employed forward at corps medical centre; and No. 3 Mobile Neurosurgical Unit under the command of Lieut.-Colonel R. Johnson, RAMC, adviser in neurosurgery to ALFSEA, at advanced base hospital level at Comilla, with an ophthalmic centre and a centre for the treatment of severe burns attached to it. Both units did invaluable work. The forward unit was located for the most important period at Shwebo and dealt with 427 head injuries of which 100 were penetrating wounds of the dura. Of the latter, 33 were fatal despite the fact that casualties reached this unit from both the Fourteenth Army and the 36th British Division of Northern Combat Area Command in the north in good time; 67 per cent. of them within 24 hours and 88 per cent. within 36 hours. No. 3 Moblie Neurosurgical Unit, to which patients from No. 2 Mobile Neurosurgical Unit were evacuated by air, a journey of two to three hours, had a busier role. Out of 640 head cases due to missiles, 258 had dural penetration. Of the latter

the mortality was as high as 29 per cent. in spite of the fact that forward conditions and the arrangements for evacuation were better at this period than ever before. It is the opinion of Lieut.-Colonel R. Johnson that this was due to the increased incidence of *B. coli* infection of the wounds which coincided with the advance of the Fourteenth Army from virgin jungle country to the cultivated dusty plains of Central Burma. Infection from this group of organisms was the most serious complication encountered and gravely limited the role of penicillin. Insufflation of calcium penicillin-sulphamethazine powder was abandoned as it was found to increase the risk. As with surgical cases, arrivals from the XV Indian Corps in the Arakan (which evacuated direct to No. 3 Mobile Neurosurgical Unit at Comilla) were in less satisfactory condition than those from the Fourteenth Army, due in the main to the difficulties and delays of evacuation from this area.

Evacuation of casualties further back from No. 3 Mobile Neurosurgical Unit was most unsatisfactory. The nearest neurosurgical unit was at Secunderabad in Southern India, a journey by sea or rail of many days. In consequence, patients had to be held at Comilla until risk of infection or other complication was over. Thus the unit became greatly overcrowded and a heavy strain was put on its resources. This state of affairs was enhanced by the fact that the centre for the treatment of severe burns was attached to this unit and administered by it until the arrival of No. 3 Maxillo-Facial Unit from India in April 1945.

Reports from other theatres have indicated certain administrative difficulties connected with the inevitably parasitic nature of these units. In this theatre the difficulties were increased owing to the fact that they were British units with no establishment to deal with Indian troops. In consequence the parent hospital was perforce an IGH(C), which had little to spare in the way of personnel or equipment. At Comilla the only site suitable for the unit was at a distance of several miles from its parent unit and this threw a still greater strain on both of them. The demands by a neurosurgical unit on X-ray facilities are always heavy and were far too much for the limited resources of an IGH. There is no doubt that an X-ray apparatus of portable type should be part of the equipment of every mobile neurosurgical unit.

MAXILLO-FACIAL SURGERY

Until April 1945, there was no special facility for maxillo-facial surgery in ALFSEA. The number of cases was not large (203 were treated by the forward surgeons of the Fourteenth Army between January and May 1945) but it was a great disadvantage that any case needing complicated or extensive skin grafting had to travel for expert attention as far as Ranchi or Secunderabad in the case of British troops, and to Lucknow in the case of Indian troops. When after repeated requests, No. 3 Maxillo-Facial Unit was eventually released from India, and set up in Comilla in conjunction with No. 3 Mobile Neurosurgical Unit and the ophthalmic centre, the flow of casualties was already

diminishing and was practically to cease soon. Nevertheless, much valuable work was done in the treatment of 200 cases of severe burns, the centre for which was taken over by the unit. The climatic conditions and the hospital amenities were by no means ideal, and although an air-conditioned ward and facilities for saline baths were in course of construction, VJ day prevented their use. There was, however, only one fatal case. On 5 May 1945 (D plus 4) the light advanced section of this unit was landed at Rangoon but had little to do (33 operations) as casualties thereafter were few.

BURNS

Burns were treated on similar lines in this theatre as in others although certain special problems arose. After shock had been overcome, the standard early treatment of the burnt area was gentle cleansing under morphia, avoiding general anaesthesia, followed by dusting with sulphanilamide, vaseline gauze dressing, wool and pressure bandages. General treatment included sulphanilamides by mouth and penicillin intramuscularly as a routine. By these means in the Fourteenth Army some 91 per cent. of major burns survived to be evacuated. In burns of large extent, however, it was intolerable and damaging for the patient in the heat of Burma to be swathed in layers of wool and pressure bandages. The loss of fluid from sweating might well equal that saved by the treatment. Judgment had to be exercised and areas more lightly burnt had to be treated with a coagulant such as gentian violet and left exposed. A second difficulty arose over evacuation. Severe burns travelled as badly by air as by other means and it was never advisable to move them from the forward unit before the third or fourth day. Some surgeons advocated that they be held until the seventh or eighth day before being evacuated to hospital. Unfortunately by that time, in forward conditions, infection was liable to supervene and the possibility of skin grafting was unduly delayed. There was usually a time between the fourth and the seventh day when the primary and secondary shock had been overcome and when the patient was in a stable enough condition to stand evacuation, but the greatest care had to be taken to avoid long waits on torrid airfields, high bumpy flights and other tests of endurance. Each case had to be judged on its merits, bearing in mind that conditions and facilities for treatment at hospital level were far more suitable than they were further forward.

Until No. 3 Maxillo-Facial Unit arrived in ALFSEA at the end of April the treatment of these cases in the later stages was somewhat haphazard. The small centre for severe burns which worked in conjunction with the mobile neurosurgical unit at Comilla could only deal with a few cases and had little special equipment. Saline baths were very little used owing to the difficulties of maintaining asepsis. As soon as cases needing extensive skin grafting or other long term measures were fit to be moved they were evacuated back to India for their final treatment. After No. 3 Maxillo-Facial Unit arrived such cases were treated by them.

The following points are noteworthy.

(i) The general impression is that Indian troops stand burns better than do the British.

(ii) Burns are grafted as soon as the sloughs are separated provided no deep epithelium is present.

(iii) All severe burns are routinely treated with a complete antimalarial course.

(iv) Pinch grafts are favoured in large burns because they cause less shock and less donor area is required, leaving large donor sites free for secondary grafting.

(v) The percentage of 'takes' has been good (almost 100 per cent.) in spite of the heat and humidity. The subsequent growth of pinch grafts has been slower than normal, due possibly to the effects of climate, or of poor diet and anaemia.

OPHTHALMIC SURGERY

Apart from the ophthalmic departments of the two African hospitals the cover was supplied by Indian ophthalmic units and spectacle centres, which were, in the main, attached to IGHs on a regional basis.

At Comilla a special ophthalmic centre derived from No. 14 BGH was set up in conjunction with No. 3 Mobile Neurosurgical Unit and to it wounds of the eye were flown from forward areas. In March 1945, an ophthalmic unit was established at each corps medical centre to deal with urgent ophthalmic wounds, which had previously had simple first aid treatment from forward general surgeons. Unfortunately this innovation was not as successful as had been hoped. There were too few units to cover the ground and fewer surgeons in them with operative experience.

The consulting ophthalmic surgeon to the War Office found that the results fell short of the average owing to lack of efficient forward treatment, and three British ophthalmic units complete with personnel and equipment were despatched from the United Kingdom as the result of his visit. These arrived too late for the war against the Japanese but they did invaluable work afterwards.

There seems no doubt that in the training of Indian ophthalmic surgeons, in war time at least, too little stress was put on operative surgery.

ENT SURGERY

British and African hospitals carried an ENT surgical specialist. IGHs did not. There were instead a number of Indian surgical units (ENT) which consisted of a recognised or graded otologist with an NCO and the appropriate instruments. These units were attached to IGHs. Although not an ideal arrangement, it worked on the whole fairly well except for a period when there was a serious shortage of otologists in ALFSEA. This took a considerable time to remedy owing to difficulties of transporting even a single individual from India to Burma.

As in other theatres, especially tropical ones, the bulk of the work was of a minor nature, the commonest condition being otitis externa.

An illuminating piece of work was done by Lieut.-Colonel A. J. Moffatt, RAMC, adviser in ENT surgery to ALFSEA. Investigating antral and sinus infections, he found that a high proportion of them was due to the *B. coli* group of organisms. These had almost certainly been inhaled with the dust which, especially in the dry season, is all pervading. The behaviour of war wounds, and especially of wounds of the brain gave his findings sombre support.

ELECTIVE AND TROPICAL SURGERY

Policy : Until the end of the war very little major surgery apart from battle surgery was undertaken in ALFSEA. The three months holding policy limited the surgeons to minor procedures and emergency measures. In any event many of the hospitals were too busy to undertake them. There was the usual quota of haemorrhoids and hydroceles. The latter, in Indians, were not so readily dealt with by tapping as in British troops. They tend to recur rapidly and usually have to be treated radically, suggesting a high incidence of inflammation of the sac wall. The operation which gave the least trouble was that of simple inversion through a small incision.

Hernia was as common as usual. They were border line cases for a three months policy and the hospitals dealt with them in quiet periods, but if busy, passed them on to India.

Few orthopaedic conditions other than fractures were retained in ALFSEA owing to lack of skilled personnel and of other facilities.

After the Japanese surrender the geographical separation from India widened and the scope of surgery in ALFSEA consequently increased, but as far as possible the policy of evacuating all those unlikely to be fit for discharge from hospital within three months was maintained. Only Indians and Indian Army personnel were then evacuated to India, British officers and other ranks being sent direct to the United Kingdom.

Special Conditions

Amoebic Dysentery: Perforation and acute intestinal obstruction calling for urgent operation seldom happened. Amoebic hepatitis usually yielded to medical treatment and it was rare for an abscess to need drainage. Surgeons, however, were continually meeting intestinal amoebiasis which simulated other conditions and had always to be on their guard to avoid unnecessary and damaging operations. In order of frequency the conditions were acute and sub-acute appendicitis, carcinoma of the rectum and chronic intestinal obstruction, (with or without a palpable tumour) and cholecystitis. Surgeons learnt in cases of doubt to try the effect of emetine before operating, and when operation had been performed with doubtful findings to treat the patient with emetine as a routine, even in the absence of histological evidence.

Amoebiasis was rife among the prisoners in Japanese hands, and in the absence of appropriate drugs was often severe and fulminating.

In desperate cases captured Australian, Dutch and British surgeons found that appendicostomy, caecostomy and especially transverse ileostomy were frequently a life-saving and even curative measure, just as had been found in the most severe forms of ulcerative colitis. A paper on this subject written by these surgeons was submitted to the War Office for publication in the autumn of 1945. It appears that control of the secondary infection can be achieved by rest and lavage of the affected bowel and that an amoebiasis not secondarily infected is not likely to cause serious symptoms. This theory is borne out by the success achieved by penicillin in treating intractable cases.

Tropical Ulcers: In parts of the Assam and Burma jungle these were very common. A few were diphtheritic but the majority had a mixed and confusing bacteriology. A large number were successfully treated with penicillin, used either locally as a compress or as intramuscular injection. Others yielded to arsenical injections, especially in Malaya and other localities where yaws was endemic. All required rest and careful dressing. This condition too was common and very severe among POW, many cases, with the limited facilities for treatment available, progressing to osteomyelitis and some requiring amputation.

Malaria: This disease did not give rise to, but very frequently complicated, surgical conditions. In spite of suppressive treatment it was so common for the severely injured man to develop overt malaria that a full therapeutic course of mepacrine was given as a routine to the seriously wounded. The same rule was applied in cases of burns or after serious operations. This complication of surgery may well arise in civil life among those suffering from latent BT malaria.

ANAESTHESIA

The adviser in anaesthesia in the Eastern Command, India, was in professional charge of anaesthetic matters in ALFSEA. On 5 March 1945, Lieut.-Colonel V. F. Hall, RAMC, was appointed adviser in anaesthetics to ALFSEA, remaining until 23 July 1945 when the appointment lapsed.

The following points are taken from his report received in October 1945.

(a) Remote control as exercised by an adviser in India was very unsatisfactory. Problems arose in the field easily solved by personal visits but not otherwise and the adviser should have an intimate knowledge of the conditions in which his forward specialists were working. It was unfortunate that a partial ban prevented his visiting the Fourteenth Army during his term of office.

(b) The work of the anaesthetists in the command generally and in forward areas in particular, was of very high standard and the way in which the standard was maintained in the face of innumerable difficulties deserves the highest praise.

(c) *Equipment:*

(i) The existing army pattern of Boyle's apparatus was too heavy and cumbersome for mobile units.

(ii) Light-weight cylinders when issued were very successful and should be standard.

(iii) Nitrous oxide apparatus should be removed from the war equipment scale of all units.

(iv) Indian equipment made during the emergency was of poor quality.

(d) *Supplies:*

(i) The problem of supply to forward units was a very difficult one. Mobile surgical units were frequently starved of nitrous oxide and carbon dioxide. Medical stores were not prepared to send cylinders forward until an equivalent number of empties were returned. Wastage should be allowed, especially as pentothal, oxygen and nitrous oxide were the commonest anaesthetics used.

(ii) In considering equipment for army use it is necessary to find a mean; the great expansion required in war implies that the standard of anaesthetists can only be moderate and it is useless to provide elaborate apparatus for them. At the same time the tendency to supply apparatus which is old fashioned and out of date is equally wrong.

(e) *Pentothal:* It was not always fully realised that the administration of sodium pentothal to a seriously ill patient can be very dangerous and that great care is needed in its use.

RADIOLOGY

Surgeons in ALFSEA had at no time adequate radiological support. There was always a shortage of both personnel and equipment. Lieut.-Colonel Hugh Davies, adviser in radiology to ALFSEA did much to improve matters in the short period of his appointment but was obliged to leave before his work was complete. The main fault was deep rooted. Not until the end of the campaign did an Indian hospital or CCS have an X-ray plant or radiologist as part of its establishment. X-ray facilities were provided by units, mobile and otherwise, which were attached to hospitals and CCSs. Each CCS had an attached mobile unit, but for 35 IGHs there were only 21 X-ray units available. British and African hospitals had the usual X-ray departments which included a portable machine for ward work. Outside these, there were only three portable machines available in ALFSEA and two of these had to be used in hospitals where there was no other set.

The impossibility of bringing X-rays to the immobilised patient prevented the proper treatment of fractures, especially of the femur, and to quote Brigadier P. E. Wiles, consultant surgeon to the Line of Communication Command and the Twelfth Army : " It is fair to say that the shortage of X-ray facilities has resulted in permanent deformity to an appreciable number of Indian patients ".

To make matters worse there was an irreparable shortage of radiographers in Indian units. Supplies were slow and irregular, at a critical period there was an almost complete lack of films and at others the quality of the films was very poor. Replacements and major repairs took

many months to effect from the base at Poona. The sets, of varying patterns and efficiency, were hard worked and could not be expected to retain their maximum efficiency without more attention than the two mobile servicing units available could give.

The work done by individuals was excellent but the service as a whole was never satisfactory.

THE TACTICAL USE OF MOBILE SURGICAL UNITS

There were no field dressing stations in this theatre comparable to those in Italy or in North West Europe. The West African field dressing station was really a small CCS which carried its own surgeon. Mobile surgical units had, therefore, to be attached to CCSs or to field ambulances. Although it was realised that the best results were obtained from these units when they were attached to a CCS, especially as the CCSs carried only one surgeon, this ideal arrangement could seldom be maintained. The nature of the terrain, the comparative isolation of the forward troops and the fact that light aircraft could only evacuate by day, made it imperative that skilled surgery be pushed further forward. For long periods the natural habitat of the mobile surgical unit was the MDS of a field ambulance. There were not enough mobile surgical units to provide reinforcement to CCSs as well. The consequence was that frequently both mobile surgical unit and CCS surgeons were seriously overworked for long stretches. For a short period when during the crossing of the Irrawaddy the forward troops were on a comparatively narrow front with fair roads and the two corps medical centres (at Mytkye and Sadaung) were readily accessible by air, the arrangement of mobile surgical units both forward with MDSs and back with CCSs worked smoothly. Even then, the shortage of field transfusion units was keenly felt.

In isolated brigade operations, such as were frequent in the Arakan, it was essential for the brigade to carry its own surgical cover but mobile surgical units could not be committed in the lesser operations by battalions or companies. When small columns such as these were to be isolated for a long time an *ad hoc* team minimally equipped was attached.

The arrangement for field surgery in the West African forces was different. Each West African field ambulance carried a graded surgeon (though no anaesthetist) on the strength. For each West African division three West African field dressing stations were available. There were in reality 100 bedded CCSs and carried a graded surgeon. This arrangement, designed for long range warfare, and of proved usefulness in West Africa, had both advantages and disadvantages. It happened that the West African division was often operating in isolated brigade groups in which the field ambulance surgeon was invaluable. The field dressing station was, however, unduly small, and the only satisfactory arrangement was to group two together.

For many of their roles in jungle warfare the establishment of the Indian mobile surgical unit was unsuitable as it required three 15 cwt. vehicles and one jeep (later five jeeps with four trailers) to move it. Where roads were absent or unsuitable for vehicles it had to be transported by mule or even by head carriage by porters. For this, individual officers commanding improvised a scale of equipment averaging a ton or less in weight, divided into suitable loads. In general the units were overweighted.

APPENDIX A

Evacuation of Surgical Casualties

AIR EVACUATION

The scheme of the evacuation of wounded by light and heavy aircraft has already been indicated. There are points important to surgery, however, which should be mentioned.

Most cases travel well by air except at height over 12,000 feet or in very bumpy weather. Unfortunately in the monsoon both these adverse conditions were commonly met in crossing the Chin Hills which rise in parts to 9,000 feet. Even so it was surprising how little harm was done, less than by a journey of a few miles over a bad road in an ambulance vehicle. The matter is discussed in great detail by the consultant surgeon, Fourteenth Army in an Appendix of the *Medical History of the Burma Campaign, November* 1944 *to May* 1945. His findings in respect of patients do not materially differ from those which have come from other theatres of war but the peculiar difficulties of air evacuation of the Burma Campaign, some of which could be avoided in the future, are to be noted.

Light Aircraft: The achievements and capacity of these are shown in great details in ALFSEA Operational Research Group Report *The Evacuation of Casualties from Forward Areas by Light Aircraft* which is, in fact, a striking tribute to the American squadrons of L 5s and the American pilots operating them. It is emphasised in this report that the outstanding success of the method was largely due to the fact that in practice the evacuation of casualties was the first priority task of these squadrons, which were under the control of the DDMS corps. This was in strong contrast to the role of heavy aircraft evacuating casualties further back as will be seen later. Light aircraft were invaluable in bringing the wounded man to the surgeon at CCS level and casualties in Burma could not otherwise have had the benefit of proper surgery in good time by any other method. But there were limitations. First was that, except in special circumstances with a strip of 400 yards or longer, they could only evacuate one casualty without an attendant in each sortie. There was no possibility of treatment, such as an (in ambulance) intravenous drip, during the flight. Even more serious from a surgical point of view was their inability to operate at night, i.e., between 1700 and 0800 hours. Many casualties brought to a field ambulance between these hours had to wait there too long for safety. This necessitated the location of mobile surgical units at MDSs to work a night shift. It became the practice for the mobile surgical unit team to rest by day, as many casualties as possible being flown straight on to the CCS, and to work all night.

Only one mobile surgical unit could be spared for each 'air head' and that at the cost of building a really efficient surgical centre at the CCS. In peak periods, therefore, the work was too hard and the most forward teams got little rest. Nor could all cases, especially the

minor ones, be operated on within the optimum period. Owing to the pressure of work on a single surgeon some casualties had to be left all night and to be evacuated for their operation to CCS the next day.

An ingenious device, 'The Brodie Landing Apparatus', was demonstrated in India to a group of officers from Headquarters ALFSEA including the BG Ops Research and the consultant surgeon who were flown as passengers on trial trips. A steel wire 500 feet long is stretched at a height of 40 feet by a simple method. A light aircraft is hauled up and hangs by a hook on a carriage running on the wire. It takes off from and lands on this carriage and is brought to a stop by a cable running to a brake drum. The take off and landing are smooth and appeared to be safe. The apparatus can be quickly erected in swampy or hilly country where no strip can be made. It had been successfully used on ships which, by steaming into the wind allows of a much shorter wire. There seems to be no *prima facie* reason why such an apparatus, erected on a hospital ship, should not be most effectively used, especially in combined operations. A recommendation was made to this effect.

Heavy Aircraft: The evacuation of casualties from CCS to hospital, in time for modern methods of wound closure to be applied, was achieved and could only have been achieved on this front by aircraft. Their routine use was a tremendous advance on any previous method, but there were certain disadvantages, the most serious of which was due to the lack of co-ordination of their control with medical necessity. Heavy aircraft carried casualties as their secondary duty only. Their primary role was to carry forward reinforcements or supplies to the fighting divisions. Theoretically this duty fitted conveniently with loading casualties at the forward airfield and their delivery at the base at which our hospitals were grouped. In fact there were numerous delays and annoyances. It was usually impossible to obtain the expected time of arrival of aircraft and patients were kept waiting on the shadeless forward airfields for hours, for the aircraft ran to a schedule and when they arrived they could not wait for patients to be brought from the CCS a mile or so away. Tactical changes forced the use of forward fields other than those at which the units were placed and pilots were not always briefed to call at the appropriate field before their return. Occasionally, especially when supply aircraft were used, they returned to what was the wrong base. Medical administration had only remote control through staff channels and it was difficult to devise a system which could successfully meet an emergency. There were, in consequence, delays and irregularities in addition to those due to weather conditions, and they increased in the later stages of the campaign, with longer flights and fewer, hard pressed, aircraft. The time lag between the primary and secondary operations was thus often prolonged and always incalculable. Undoubtedly some of the failures were due to this factor.

The aircraft themselves were not especially fitted for ambulance work apart from the usual racks and slings for stretchers. The heating system often failed, oxygen was seldom, if ever, available nor were there

attendant orderlies other than those temporarily supplied with difficulty by forward units.

It is obvious that an ideal air evacuation service will not be attained until specially equipped ambulance aircraft are earmarked for casualty evacuation of wounded as their primary task. When, as was the case in Burma, this is impracticable, an improvement in inter-service staff work is essential for surgical efficiency.

WATER-BORNE EVACUATION

Combined Operations: Experience in several small scale combined operations on the Arakan coast taught the difficulties of the management of surgical casualties in this type of warfare. The arrangements made for the larger enterprises to capture Rangoon and Singapore were not tested, but personal observation of the mechanism of evacuation of the few casualties sustained at Rangoon was disquieting.

Unless the distance by sea from beach-head to base is short (as in Normandy) modern methods of two-stage battle surgery cannot easily be used. To maintain a rapid and continuous stream of evacuation many hospital ships or carriers are needed—many more than were ever available in South East Asia. LSTs used so successfully from Normandy beaches were judged to be unsuitable for a tropical climate especially over the distances involved as the temperature in the tank deck becomes very high. In the early stages of a sea-borne attack there are two surgical problems; to chose first the place for preliminary surgery and second the place for definitive surgery. On the beach-head surgical operations must be limited strictly to essential priorities until a holding unit—such as a CCS—can be opened. Until that time hospital ships, reinforced by extra surgical teams, lying off the beach-heads can act as floating CCSs, or, if the carry by sea is short, patients can be brought direct to base hospitals for their first surgical operation. In the Arakan operations and at Rangoon the carry was long and the first alternative was attempted, but was prejudiced by the reluctance of the Royal Navy to allow a hospital ship to be within reach of shore craft on 'D' Day. Personnel transports, partially converted to be used as hospital carriers on their return trip, were designed to take the earliest casualties but were never tested in this capacity. The schemes were complicated by the lack of liaison between the services over the movements of casualty evacuation craft, by the lack of communication from shore to hospital ships and carriers lying out of sight of land, and by other factors. Not the least of these was the reluctance to use a ship uneconomically, i.e., to move it unless approximately filled. This tended to spoil a regular schedule and to prolong the evacuation time of any individual patient. Rhythm of evacuation so necessary to successful early closure of wounds was interrupted by unpredictable irregularity, especially as the bases were four or five days sailing time distant. It was no answer to attempt delayed closure in the hospital ships even when their facilities permitted it. On arrival at the port of disembarkation the casualties would still, for the most part, have to suffer an arduous journey by land which would have caused recently closed wounds to break down or suppurate.

Some of these problems were capable of solution by the employment of more carrier ships, or of seaplane aircraft and by closer attention to administrative detail especially between shore and sea ; but not all of them.

Faced with adverse circumstances, which are inevitable, the surgeon's duty is to modify his methods and there is no doubt that combined operations on a large scale in South East Asia would have been a case in point. It is advisable in the early stages of a landing to treat wounds by excision and immobilisation in plaster of paris at the earliest opportunity, giving them safety and comfort in transit over a considerable period, and not to attempt to follow a strict chronological ritual of wound closure.

ROAD AND RAIL EVACUATION

Motor Ambulance Vehicles: The traumatising effect of journeys over bad roads is well known and was the subject of special investigation on the Italian front. With very few exceptions the roads in this theatre were deplorable ; many were mere tracks fit only for stretcher carrying jeeps. As already indicated this method of evacuation was perforce confined to very short journeys but the bad effect of these was always to be seen.

Ambulance Trains: This excellent method of transporting the wounded was unfortunately limited in this theatre to a lateral line connecting Chittagong with Comilla, Agartala and Dacca. The whole journey took less than 24 hours when the paths were clear. Although the railway was invaluable in distributing the casualties among the group of hospitals, such a journey frequently involved at least one night at a staging hospital before entraining and one night in the holding hospital before treatment could be undertaken. A loss of three precious days was thus difficult to avoid. When for non-medical reasons the bulk of casualties were, for a time, deplaned at Chittagong an attempt was made to sort them on the airfield and to entrain all those fit for the journey immediately. Difficulties were found in the lack of adequate facilities on the airfield and in the irregularity in the numbers and times of arrival of the aircraft.

SUMMARY

War surgery, if it is to reach its highest level, is dependent on timely evacuation. When the tactical situation or the material resources of a force does not allow optimum evacuation, surgery must be modified to suit the circumstances, but the results will fall short of the best. That circumstances were made so favourable for the surgeon in spite of the great difficulties inherent in this theatre was due to the readiness with which administrative medical officers from the DMS downwards appreciated the situation and the unhesitating and practical support which they gave to the requirements of surgery.

CHAPTER XXXVIII

Surgical Organisation—India Command

The surgical cover for the Army in India at the outbreak of World War II, though adequate for peace time, was far from adequate in case of war. The deficiencies in equipment and specialists were some of the major problems which became difficult to solve. The equipment tables that were in force in 1919, with minor changes, were being followed. For example the general hospitals mobilised in 1939, went out of the country with only skin traction and Thomas' splints for the lower limb fractures and Robert Jones' splints for upper limb fractures. Specialists like anaesthetists, ophthalmologists, oto-rhino-laryngologists and radiologists did not exist in the establishment of field medical units. There were no special trades like operation theatre attendant or transfusion orderlies or radiographers amongst VCOs and IORs.

EQUIPMENT

Early in 1940, the equipment tables were revised and some items of relatively modern equipment were made available for the treatment of injuries and administration of anaesthesia. New items of equipment continued to be added to the scales from time to time. In April and May 1942, the scales were examined in great detail and steps were taken to modernise the equipment. This immediately raised the almost insoluble question of supply.

With the progress of the war, most of the instruments and appliances, previously imported from abroad, became difficult to obtain. The first important step to improve the situation was taken in May 1941, when the DGIMS convened the Surgical Instruments Standardisation Committee, to which 23 leading surgeons in India embracing all branches of surgery were invited. This committee compiled schedules of the various standard types of the surgical instruments and appliances required for all branches of surgery, bearing in mind the need for a minimum number of types consistent with efficiency, and the desirability of selecting as far as practicable the types that could be manufactured in India, and preferably the simple and easily manufactured types in order to facilitate rapid production. About the same time it also became necessary to appoint a technical officer to assist the Directorate of Production. Forward provisioning and central purchase policy led to large expansion in the production of instruments. Manufacturers under the stimulus of orders for a large number of instruments for delivery over long period were encouraged to expand their factories.[1]

Serious difficulties in the manufacture of certain specialised instruments, however, continued. A special committee, therefore, examined

[1] H/5/56/H(M).

this question in November/December 1942. The recommendations of this committee helped a great deal to solve the difficulty. The committee, while making the recommendations, also observed that from the evidence placed before them they were of the opinion that the manufacturers hitherto employed were unable and in fact had failed for various reasons inherent in the then existing organisation to supply the necessary quantity of instruments of requisite quality.[2] Despite many difficulties the situation steadily improved during 1943-45.

With cessation of hostilities in Europe, it was possible to import surgical equipment from the United Kingdom, and the DMS requested the Supply Department to cancel any orders that were placed against 1945 demand. On 31 July 1945, the surgical instrument production in India on the vast scale necessary for the Defence Services was thus brought to an abrupt end.[3] One of the members of the committee held in December 1942, in a letter pointed out that he was strongly of the opinion that the then existing machinery was unsuitable for war time intensive production of surgical instruments and there were some really good engineering firms which could be utilised for production of surgical instruments on a large scale.[4] It must be emphasised here that to meet any future emergency not only the surgical instrument industry in peace time should be improved, but should be so planned as to be able to expand rapidly to meet the war time requirements.

SPECIALISTS

From the very beginning, the acute shortage of surgical specialists was felt. The deficiency of about 50 per cent. of the requirement continued to persist despite the introduction of the following measures :—

(i) Direct recruitment of specialists.

(ii) Grant of rank of major to all recognised specialists provided one was holding a specialist appointment on a war establishment.

(iii) Relaxation in the standards for grading firstly because there was an all-round shortage of surgeons and secondly to secure grading for officers serving in commands overseas who were considered experienced, but had no opportunity to sit for higher examination due to exigencies of service.

(iv) Training of any general duty medical officer who showed an aptitude for surgery in specially selected training centre.

A pool of 35 surgical specialists was created in 1942. These specialists were mainly posted for duty in garrison hospitals in India which had otherwise no specialist authorised in the establishment. In 1943, a surgical specialist was authorised in every hospital of 300 beds and over. At the same time surgical and medical divisions were created in hospitals of 600 beds and more. Each of these divisions was placed under the charge of a specialist with the rank of major.[5] Later in

[2] A/6/37/H(M).
[3] H/5/56/H(M).
[4] A/6/37/H(M).
[5] F/2195/H(M), F/2160/H(M).

December 1942, the rank of lieut.-colonel was authorised to officer-in-charge of a division in a hospital of 1,000 beds, but this decision was not applicable to garrison hospitals.[6]

Up to 1943, there were only two large training centres for surgeons. This was inevitable because the surgical work in quantity at that time was limited to a few centres. As the war progressed in the east, it was possible to send trainees to other centres.

Prior to the end of 1944, the surgical direction of the forces in Burma was from India. Thereafter, consultants were appointed to ALFSEA and the Fourteenth Army.[7] The surgical cover, however, continued to be provided to ALFSEA by the India Command. It must be added that it was not possible at any time to provide the number of surgeons required. The number of surgeons required and available in India and ALFSEA is given below :—

Assets and liabilities—Surgeons in India and ALFSEA.[8]

	1944		1945		1946	
	March	July	January	July	January	March
Liabilities ...	401	386	495	535	524	453
Assets	243	238	261	293	241	241
Deficit	158	148	234	242	283	212

The number of surgeons authorised in different units changed from time to time.

The number of specialists authorised for the Army in India and ALFSEA in 1939[9] and 1945[10] was as follows :—

Specialists	1939	July 1945	
	Authorised	Authorised	Available
Surgeons	20	535	293
Ophthalmologists	8	85	66
Neurologists	...	4	8
Maxillo-facial surgeons	...	6	6
Oto-rhino-laryngologists	4	77	48

[6] F/2273/H(M).
[7] See Chapter XXXVII.
[8] H/3/26/H(M), A/1/8/H(M), A/1/14/H(M), A/1/20/H(M), A/1/22/H(M).
[9] *Regulations for the Medical Services, Army in India.*
[10] A/1/14/H(M).

MALE NURSES AND RADIOGRAPHERS

On the creation of the IAMC in 1943, recruitment was opened to qualified persons directly to VCO's rank as male nurses, radiographers and laboratory assistants. Trades like operating room assistants and blood transfusion orderlies were also introduced.

CONSULTANTS

In May 1941, appointments of consultants were sanctioned.[11] The consultants with the rank of colonel were to be selected from amongst medical officers on the active or retired list and from private practitioners. But it was not until January 1942, that the specific appointment of consultant surgeon, India Command, was sanctioned,[12] and the first incumbent Brigadier Grant Massie took over the appointment in April 1942. In the meantime sanction was obtained for the appointment of a consultant surgeon for the Southern Command in December 1941.[13] Further appointments of consultant surgeons for the Eastern Army and the Central Command were created in January 1943[14] and October 1944,[15] respectively. The latter was also responsible for the North Western Army.

In pursuance of War Office policy,[16] it was later decided to grant the local rank of brigadier to both the consultants at the GHQ and the consultants in armies/commands with effect from the date they had taken over their appointments.

The appointment of an adviser in neurosurgery (lieut.-colonel) India Command was sanctioned in April 1945,[17] and the officer commanding of the neurosurgical centre was appointed to this post. He had to carry on the duties of the adviser in addition to his normal duties at the neurosurgical centre. This appointment lapsed after September 1945.

In January 1946, the appointments of consultant surgeons in armies/commands were downgraded[18] to advisers (lieut.-colonel) and the local rank of brigadier for the consultant at GHQ was also discontinued.

FIELD UNITS

Early in 1940, it became apparent that warfare was not going to be of the static trench type of World War I. The mobile warfare made it difficult for the then existing medical organisation to render adequate surgical aid to the wounded in the front line and put a great strain on the surgeons in the CCSs and field hospitals. The mobile surgical units were, therefore, formed. These could be attached to a field ambulance, CCS or general hospital. Special teams to deal with maxillo-facial, neurosurgical, thoracic cases, etc., were also formed.

11 F/Z-21017/H(M).
12 F/Z-26271/H(M).
13 F/2002/H(M).
14 F/2132/H(M).
15 F/0904/1/H(M).
16 F/3606/12/H(M).
17 F/3606/13/DMSI(c).
18 F/0904/9/H(M).

Reports from mobilised general hospitals overseas showed that they required aid of specialist units like X-ray, ENT and ophthalmological units. It was not always possible to attach these units to all hospitals. They were usually allocated to a group of units.

SPECIALIST CENTRES

Immediately after it was decided that India would be the main base for receiving casualties from Burma and SEAC as well as the Middle East, the existing hospitals had to be expanded and new hospitals had to be raised in the country. These hospitals were required to provide specialist treatment also like orthopaedic and neurosurgical. By 1944, the specialist centres were located as follows :—

Hospital	*Location*	*Centres*
No. 1 IBGH(BT)	Karachi	ENT
No. 2 IBGH(IT)	Kirkee	Neurology
No. 3 IBGH(BT)	Poona	Orthopaedic, peripheral nerve injury, neurosurgery, ophthalmological and ENT.
No. 6 IBGH(IT)	Karachi	Ophthalmological and orthopaedic.
No. 7 IBGH(IT)	Kirkee	Artificial limb, peripheral nerve injury, neurosurgery, ENT and orthopaedic.
No. 126 IBGH(BT)	Poona	Artificial limb and neurology.
No. 128 IBGH(BT)	Secunderabad	Orthopaedic
No. 130 IBGH(IT)	Lucknow	ENT and orthopaedic
No. 133 IBGH(BT)	Bareilly	Orthopaedic, plastic surgery, ophthalmological and ENT
No. 136 IBGH(BT)	Dehra Dun	Ophthalmological and ENT
No. 137 IBGH(IT)	Secunderabad	Ophthalmological and ENT
No. 139 IBGH(BT)	Ranchi	Orthopaedic

ORTHOPAEDIC CENTRES

The orthopaedic centres were designed for the treatment of severe injuries of bones and joints. The establishment of a centre allowed for an orthopaedic surgeon and masseurs and other technical staff as well as extra nursing personnel.[19] On 1 July 1942, 200 beds for orthopaedic cases were started at Karachi. By January 1943, 3,600 orthopaedic beds were provided in seven centres. The orthopaedic centres were authorised special establishment and equipment including those required for electrophysiotherapy, occupational and diversional therapy.

NEUROSURGICAL CENTRE AND PERIPHERAL NERVE INJURY CENTRE

On 31 July 1944, a neurosurgical centre was opened in No. 126 IBGH(BT), Poona, with Indian cases at No. 7 IBGH(IT), Kirkee. In December 1944, the neurosurgical centre from Poona was moved to

[19] H/3/26.

Secunderabad. Similarly two peripheral nerve injury centres were opened in December 1943, one in No. 3 IBGH, (BT) Poona and the other in No. 7 IBGH (IT), Kirkee. The British centre at Poona was also later moved to Secunderabad.

PLASTIC SURGERY CENTRE

Plastic surgery was undertaken by No. 3 Maxillo-Facial Unit which treated both British and Indian cases.

PHYSIOTHERAPY AND REHABILITATION CENTRE

Physiotherapy and rehabilitation centres formed part of orthopaedic centres. The object of the rehabilitation centres was to teach every patient during hospital treatment, a trade for which he possessed a natural aptitude and which at the same time would be of use to him in post-hospital or post-war resettlement. Occupational therapy was thus the most important treatment at these centres. The other function was diversional therapy. Red Cross workers were attached to almost all such centres in the base hospitals. Trades in which training was imparted, covered a wide range including such trades as carpentry, smithy, needlework, knitting, basket-weaving, tailoring, spinning and weaving.

BLOOD TRANSFUSION

Shock being the main surgical problem among the battle casualties, it attracted great attention during the war. General hospitals mobilised in 1939 were equipped with Robertson blood transfusion apparatus and Kimpton-Brown tubes. These were found too time consuming to be of practical use in war. Blood transfusion units were, therefore, raised and plasma, both wet and dry, was made available to the units operating in forward area. A base blood transfusion unit was raised in 1942 and an advanced base transfusion unit and blood storage unit in 1943.

WAR WOUNDS COMMITTEE (PENICILLIN)

This committee was formed at GHQ in July 1944, with consultant surgeon as chairman. The object was to consider the disposal of large supplies of penicillin due to arrive in India.

At the first meeting it was agreed that the arrival of large supplies should not in any way affect the arrangements to establish two centres, one in the Fourteenth Army area and the other in India to investigate the surgery of war wounds and *pari passu* the use of penicillin. The centre in India was visualised to become a teaching as well as a research centre. Close liaison between surgeons and pathologists at the two centres was considered desirable.

In the first instance the use of large supplies was limited to the well equipped hospitals; cases from other hospitals when necessary were transferred to these hospitals. Cases treated in the Fourteenth Army centre, were, if evacuated, sent to the centre in India.

The centre in India was formed in a base hospital in Poona with a lieut.-colonel in charge. This appointment remained in force for a period of three months only.[20]

[20] F/5921/27/H(M).

CHAPTER XXXIX

Aid given by Civilian Institutions.

The military medical services had to depend a great deal on the help given by different Government departments and civilian research institutions. The assistance given by the Malaria Institute of India, Delhi, and Nutrition Research Laboratories, Coonoor, are discussed in the volume on *Prevention of Diseases, Malaria Control and Nutrition.* Some of the investigations made by individual workers including officers of the Directorate General, Industries and Supply, have been incorporated in Chapter XL—Biochemical Research. Brief reference to the work done in some of the other institutions is made in the following pages. The aid given by the Central Research Institute, Kasauli, is discussed relatively in detail, for this institute has been the main source of supply of vaccine and sera to the armed forces.

The studies on such subjects as soya-bean milk, glandular products, penicillin, and infantile cirrhosis at the Indian Institute of Science or antibiotics, steroids, antimalarial drugs, alkaloids of stephenia glabra, kakra singhi, and allium sativum at the laboratories of the Council of Scientific and Industrial Research have not been discussed here. The following account only indicates the type and extent of the work done directly or indirectly for the armed forces by some of the institutions and is conditioned by the information available. It may, therefore, be added that the following observations neither relate all the activities of the research institutions nor discuss the work done by all investigators in India during the war.

(i) ALL INDIA INSTITUTE OF HYGIENE AND PUBLIC HEALTH, CALCUTTA

From 1939, some of the normal academic activities of the institute had to be curtailed to enable it to do war work of one kind or another. The main categories of work so undertaken were as follows. Several special courses of instruction in blood transfusion, diagnosis of tropical diseases, tropical sanitation, control of malaria, etc., were arranged for the benefit of army personnel serving in Calcutta area. Though the institute did not have a manufacturing laboratory, it undertook the responsibility of running a large blood bank and processed not only blood plasma and serum but also other kinds of transfusion material (protein hydrolysates, glucose saline, albumin, etc.) for issue to the civil and military authorities. It also manufactured some essential chemicals which were difficult to obtain.

As there was a considerable demand for expert advice on matters connected with local health and sanitary problems, the senior professors of the institute functioned as advisers to the civil and military organisations as and when required.

The army authorities were often in need of laboratory service in connection with their medical and public health work. The institute organised and offered such services.

Due to the everincreasing demand and shortage of supplies many drugs, chemicals and biologicals of non-standard makes had been purchased for army use and these had to be tested for quality and potency before issue. The institute did a fair amount of the testing work of these products.

The work referred to above was conducted mainly by the sections of microbiology, biochemistry and sanitary engineering. The director of the institute organised the Calcutta Blood Bank and ran it with the collaboration of the professors of the above three sections. An account of the work done by each section of the institute is given below.

MICROBIOLOGY SECTION

Course on Laboratory Diagnosis of Tropical Diseases to US and British Army Technicians : This course was specially designed to train NCOs and other army personnel to perform various laboratory tests used in diagnosis. The American army technicians, when they first came to India, were not very much acquainted with the tests employed in the diagnosis of tropical diseases prevalent in India. The US Army was in need of trained technicians and they sent three batches of students, 25 in all, for training. The British Army later on sent one batch of 24 technicians to take this course. Amongst the students some had received training in general microbiological laboratory work previously while others were raw under-graduates who had received no previous training. The duration of the course, therefore, had to be varied according to the type of students. It varied from four to six weeks. In the six weeks' training, there were 200 hours of work, of which 50 were used for theoretical lectures and 150 for practical work; and in the four weeks' course there were 140 hours in all, of which 30 were for lectures and 110 for practical work. A manual of microbiological technique (Krishnan, 1945) was prepared by the institute and printed by the Government and distributed to the students. The laboratory diagnosis of the following diseases were dealt with in detail :—

(i) Viral—rabies and infectious mononucleosis.
(ii) Rickettsial—typhus all forms.
(iii) Bacterial—enteric fevers, dysentery, cholera, plague, gonorrhoea and brucellosis.
(iv) Fungal—ringworm and other skin infections.
(v) Spirochaetal—syphilis, Weil's disease, rat bite fever and relapsing fever.
(vi) Protozoal—malaria, kala-azar, amoebiasis and giardiasis.
(vii) Helminthic—ancylostomiasis, filariasis and cestodiasis.

Training in preparation of strains and culture media, use of laboratory animals and serological tests employed in diagnostic work were given.

Course on Blood Grouping and Blood Transfusion to ARP Civil and Military Officers: This course was a short one lasting a week, and to it only medical officers were admitted. In all six batches of students were

trained and in each batch the number of students varied between 30 and 50. In all 244 civilian medical officers deputed by the Government were trained along with 23 army medical officers. Lectures, demonstrations and discussions were held on the following subjects :—

(i) Blood grouping—Principle and technique including collection and preparation of reagents, interpretation of results, fallacies, etc.

(ii) Physiological pathology of shock—Theoretical consideration and principles of combating shock.

(iii) Transfusion materials—Blood plasma and serum (liquid and desiccated), albumin, protein hydrolysates, glucose saline, gum saline, etc., preparation, storage, use, relative merits and demerits of each. Methods of giving transfusion, complications and their avoidance.

(iv) Organisation of blood bank and blood transfusion service, civil and military—review and recommendations.

The section conducted the work of testing various types of disinfectants, drugs, prophylactic vaccines and antisera. The Calcutta area being the base of operations enormous quantities of these had been purchased from different commercial firms. On receipt of complaints that some of these were not of good quality, samples were sent to the institute from time to time for testing by both civil and military authorities. Several batches of antitetanic serum, typhoid and cholera vaccines, quinine ampoules and disinfectants were received and examined. Some of these failed to satisfy the prescribed standard for purity or potency. In all 246 samples were examined and 67 of these were found unsatisfactory. The following findings are of special interest. One batch of antitetanic serum hardly contained any antitoxin. Several quinine ampoules contained less than half the standard strength and cholera and typhoid vaccines were frequently found contaminated or below standard in potency.

Numerous samples of aerated water and tinned food were received for bacteriological examination. In all 538 samples of aerated water were examined and many of these were of poor quality. In one instance, an aerated water factory was visited and improvements suggested for bringing up their product to standard quality. In this connection, certain standards were fixed for determining the quality of aerated water for which no previous standard had been prescribed.

The section undertook the manufacture of certain drugs and chemicals which were difficult to obtain due to the war or had gone up in price very much. Cortical hormone of high potency for the treatment of shock, peptone and mannose of high purity for bacteriological work, protein hydrolysates, hardysed blood proteins and albumin for transfusion purposes were not readily available for use. To meet the increasing demand for these, attempts had to be made to prepare them locally. All these were prepared for the first time in this country initially on a laboratory scale and later a suitable technique was evolved for large scale preparation.

Bacteriological peptone was selling at Rs. 30 to Rs. 50 a pound and many of the brands obtained from the market failed to allow *Bact. shiga* to grow. By digesting pork which was the cheapest meat available at the time with papain, a brand of peptone was prepared which was of high bacteriological quality. The cost of manufacture of this peptone was only Rs. 8 per pound. The institute prepared nearly 200 pounds of this peptone and used it in its own laboratories and supplied the local army laboratories. This brand allowed *Bact. shiga* which was the test organism to grow well. (Krishnan and Narayanan, 1941).

Mannose—a sugar required in connection with cholera work was selling at nearly Rs. 50 an ounce and was difficult to obtain. A method of manufacture of this sugar from locally available raw material was developed and in all 20 ounces of it was made. The cost of manufacture was about Rs. 12 an ounce (Narayanan, 1941).

Potent cortical hormone was being reported to be of value in the treatment of shock. The few commercial samples available were examined but found to be unsatisfactory. Attempts were made to prepare it, and a very potent cortical hormone was successfully prepared, its efficacy was established by testing on bilaterally adrenalectomised mice. In all about 200 cc. of it were made and distributed for use in the local hospitals (Krishnan, 1940).

Glucose saline and pyrogen-free distilled water suitable for transfusion were in great demand. Thousands of bottles of these were prepared and issued to army and civil authorities.

The section was responsible for the entire bacteriological and processing work of the blood bank. In addition, it was also responsible for the enormous amount of work entailed in sterilisation of glassware and equipment used by the various sections. Sterilisation facilities available in two of the hospitals close by were also fully utilised, and three shifts arranged daily. All tests on the donated and processed blood were done. In all 1,06,506 tests were performed—grouping—59,079, Kahn tests—44,456, and sterility tests—2,971.

There was no test available for finding out the quality of processed serum or plasma or other transfusion material. A special test called the 'cat test' was elaborated. It was tried out independently by the Haffkine Institute and found satisfactory. It was finally accepted as the standard test for transfusion material of all kinds including human serum and plasma. The test may be briefly described as follows :—

A healthy adult cat is anaesthetised and bled to the point of shock, i.e., about 40 to 60 cc. of blood are removed slowly from the jugular vein, till the blood pressure which is about 100 to 110 mm. is brought down to about 50 mm. The material to be tested is then injected into the vein at the same rate at which the bleeding was effected (4 cc. per minute) and the quantity of material given being equivalent to the amount of blood removed (Krishnan, 1944). The results were classified into three categories from the kymograph tracings obtained :—

Class I— The blood pressure goes up to near about the original level (90 to 100 mm.), and is maintained at that level for one hour or more. No twitching of muscles or respiratory distress is noticed.

Class II— Blood pressure rises to about two-thirds to three-fourths of the original level and is maintained for an hour. No respiratory distress occurs. Slight twitching may be present in some but the animal survives for an hour at least.

Class III—Blood pressure may rise a little or show a tendency to fall. Respiratory distress and twitching of muscles are marked. Animal usually dies during transfusion or within a few minutes after transfusion.

Samples conforming to Classes I and II can be used safely, but Class III samples are to be rejected.

The incidence of bowel diseases in the American troops stationed in the Bengal-Assam area was found to be high. Water and ice-cream used by the troops were suspected. In this connection the institute undertook to carry out routine examination of all water and ice-cream used by the troops. In all 1,039 water samples from various parts of Bengal and Assam including Calcutta, and 312 ice-cream samples were tested bacteriologically. Recommendations were also made to improve the quality of water from time to time. A special investigation was undertaken to improve the standard of ice-cream which was of poor bacteriological quality. The main manufacturing concern was inspected and every step in manufacture thoroughly checked up bacteriologically. Not only were standards of quality for ice-cream fixed but also improvements were effected in some of the stages in the manufacture that were defective. This led to a great reduction in the incidence of bowel diseases. (Krishnan, Ghosal and Banerjea, 1944).

The American Army employed large numbers of Indian cooks, who had to be examined and certified before employment. Their blood and stool were tested for various infective diseases and the carrier state. The section examined 642 cooks and found that 6 per cent. had syphilis, 8 per cent. bacterial dysentery, 3 per cent. amoebic dysentery, 5 per cent. giardiasis, 91 per cent. intestinal helminths of one kind or another, 8 per cent. skin diseases and 1 per cent. tuberculosis.

Throughout the war period the American Army, Chinese Northern Combat Area Command and the American Red Cross Association made use of the laboratory facilities available at the institute for examination of some of their clinical pathological material. In all 3,961 samples of blood, urine, faeces, tissue fluids and tissue sections were examined. Cases of infectious mononucleosis and typhus were first diagnosed here. Strains of scrub typhus rickettsiae were isolated by mouse inoculation and sent to USA for vaccine preparation. Large amounts of antigen for the Weil-Felix tests were prepared and supplied to US Army laboratories for a time. The superiority of pathogenicity test in white mice over the Weil-Felix test in the diagnosis of scrub typhus was clearly established.

BIOCHEMISTRY SECTION

This section developed special techniques for the preparation of important concentrated foodstuffs from raw material available in India. In this connection special mention may be made of the following :—

(i) Vitamin C concentrate in the form of *Amla* juice extract was prepared in large quantities by special technique using high vacuum desiccation. On analysis this product was found to contain over 200 mg. of Vitamin C per g. of dried powdered extract.

(ii) A technique was developed for the synthesis of vitamin B_1. This technique is simpler than the previous techniques described (Sankaran, 1944, Swaminathan, 1946).

(iii) Laboratory investigations were conducted for the molecular distillation of vitamin A and D, and after developing a suitable technique, schemes for the distillation of vitamin A and D from fish liver oils were submitted to the Government.

(iv) At the request of the Naval Headquarters, in connection with the Burma Campaign, a concentrated, portable complete food was prepared in the form of biscuits. These were meant for use of the ship's crew in the event of the ship being torpedoed. Each biscuit contained all the essential food ingredients and a man had to take one pound of it to obtain the requisite nourishment per day. One thousand pounds of biscuits were prepared and supplied to the navy. They were reported to be wholesome and to possess good keeping quality. Samples consumed three years after manufacture were reported to be satisfactory by the navy.

(v) In the early years of the war when DDT had not come into use, pyrethrum flowers were processed by a special Soxhlet technique using aviation petrol as solvent, and an extract with high pyrethrum content was manufactured. Five hundred gallons of this extract were prepared and supplied. It was reported to be of the same strength as Pyrocide 20 which was the best extract known at the time and was to be used after diluting it hundred times in kerosene oil.

The section undertook routine analysis and assay of preserved foods sent by the military food laboratory, the Food Directorate, the Imperial Institute of Sugar Technology and the Chinese National Government. In all 120 samples were analysed and the analysis consisted of estimations for vitamins A, B, C and D. In the technique employed, spectrographic, chemical and biological methods were used.

In collaboration with the section of sanitary engineering the 'adtevac'—a pilot plant for desiccating processed liquid plasma and serum—was built up locally by indigenous talent and material. The design of the plant was based on successful experiments on desiccation carried out on a laboratory scale. The working of the plant consisted of pre-freezing the serum or plasma, regeneration and charging of silica gel and producing a high vacuum in the desiccator while maintaining thermal control over the frozen plasma or serum and the gel. The end point of desiccation was attained by the maintenance of a vacuum of the order of 200 microns of mercury absolute pressure or less

for about 12 hours. This produces a dry powder with a moisture content of less than 1 per cent. and of high reconstitutability. The construction of the pilot plant gave confidence to the workers that problems hitherto considered impossible to solve locally can be solved when the necessity arises.

PUBLIC HEALTH ENGINEERING SECTION

Courses on Sanitation and Malaria Control: This section was called upon to train various categories of military personnel from July 1942 to July 1944. The NCOs trained were orderlies in charge of arrangements for water supplies, excreta disposal and malaria control in camps. Ten such courses were held for batches of 9 to 19 NCOs at a time. The courses consisted of lectures on the maintenance and conservation of water sources, tube wells, care of filters, field disinfection of water, use of residual chlorine outfit, construction and maintenance of camp latrines, elementary bionomics of anopheline vectors, and methods of malaria control. Practical demonstrations were arranged after each lecture in the rural areas.

In collaboration with the microbiology section two short courses were conducted for 24 officers of the RAMC. These officers were given training in malaria control through a series of lectures and practical demonstrations on the entomology of anopheline vectors, their breeding places and habits, antilarval measures and adult spray killing methods.

Three courses, lasting about six days each, were conducted for 54 medical officers deputed from the IMS and IAMC and 12 sanitary assistants for emergency work in connection with the Bengal famine. They were given lectures and practical demonstrations in rural water supplies, their disinfection and maintenance, rural and camp sanitation such as construction of latrines, manure pits, disposal of refuse, etc., and malaria control.

A course in malaria control was conducted for two weeks to train five malaria inspectors of the Asansol Board of Mines. Another course lasting four weeks was conducted to train nine Chinese Army doctors (deputed by the Chinese Government) in malaria control, water purification and field sanitation.

In all 17 courses were held and 244 persons were trained in connection with the war effort.

To meet the difficulty experienced in obtaining apparatus for field disinfection of water supplies in camp, sanitary engineering section evolved a modified Horrocks's outfit with orthotoludine standards for estimation of residual chlorine (Bhaskaran, Sabnis, Chandrasekar and Subramanyan, 1944). About 60 such outfits were supplied to the army medical officers posted for duty in connection with the Bengal famine. The cost of these field disinfection outfits was about Rs. 2,000 in all. These have proved cheap and valuable and the section has since been manufacturing and supplying a number of these

outfits to municipalities and health departments. The section manufactured and supplied a number of pH comparators also during the war to the US Army technicians for use on field water supplies.

When the Burma Campaign was in full swing, malaria control had to be effected by adult spray killing with pyrethrum extracts on a very large scale. Hand sprayers were not adequate for the task. An improved type of pressure sprayer was evolved at the institute. This was somewhat on the pattern of the DeVilbiss sprayer. It consisted of a two inches diameter air pump in a compressed air container fitted with a pressure gauge and a spray gun with a nozzle of 1 mm. diameter on a graduated glass container. One man could work the pump and maintain a constant pressure at 15 lbs. per square inch while the other could spray pyrethrum extracts about three or four times as fast as an ordinary hand sprayer. Almost all parts of this outfit were manufactured locally and cost approximately Rs. 100. About 900 such sprayers, named 'Kapur sprayers', were manufactured and inspected and tested by arrangement with various workshops and supplied to the U.S. Army for malaria control work in the Burma Campaign.

When the Government of India decided to establish a blood bank for military and civil use at the All India Institute of Hygiene and Public Health, Calcutta, in January 1942, various engineering problems arose and the sanitary engineering section participated in the venture. The clinic and processing room of the blood bank had to be air-conditioned and aerial contamination had to be reduced to a minimum. A cold room had to be built for storage of whole blood and serum below 5 °C. Arrangements had to be made for desiccation of serum and plasma so that it could be preserved indefinitely and transported easily. The air-conditioning equipment and cooling plant were installed after technical scrutiny and approval by the sanitary engineering section. The processing room was also built in consultation with the section.

As it was difficult at that time to secure shipping space and import the required plant for frozen desiccation of serum and plasma, the Indian Research Fund Association approved the proposal to build the above mentioned 'adtevac'. The sanitary engineering and the biochemistry sections worked in close collaboration. The manufacture of 'adtevac' was commenced in the East Indian Railway workshops, Messrs. Gresham and Craven's workshops and the Magnolia Dairy Products workshops under the supervision of the two sections. The plant passed preliminary tests in the shops and was assembled at the institute early in September 1942. The design of this machine incorporated some novel features. It had its own self-contained freezing plant, hot and cold water circulation, accurate low temperature thermometry, efficient heat transference in vacuum of a high order, and electric oven for regeneration of silica gel. The vacuum joints and taps were designed and made locally and proved quite efficient.

The section designed a container for transport of yellow fever vaccine under specified conditions of temperature across long distances

in India. It also designed a portable box for transporting blood at a temperature not exceeding 5°C. from mofussil stations to headquarters within 24 hours. This design was adopted by the blood banks all over the country.

BLOOD BANK

A scheme was prepared in consultation with the professors of microbiology and biochemistry for the establishment of a large central blood bank at the institute. This was approved by the Government of India and the Calcutta Blood Bank was established. Processing, testing and research sections were under control of the professor of microbiology. The desiccation section was under the supervision of the professor of biochemistry. The whole organisation was financed jointly by the Government of India, the Indian Research Fund Association and the Red Cross Society of India. The blood bank started functioning early in January 1942. The extent of the popularity of the Calcutta Blood Bank can be gauged from the fact that within a few months of its starting it had to be expanded for 750 to 1,000 donors a week instead of 200 donors a week as originally planned. There was a panel of voluntry donors consisting of civilians and army personnel who maintained the outstanding success of the organisation uninterruptedly. To sustain the interest of the donors they were awarded medals with Red Cross sign or a bar as a token of appreciation of their valuable contribution to the blood bank. The director assisted by a propaganda officer was personally responsible for enlisting donors and the panel was always full.

Collection of blood was done chiefly in the main clinic which was located in the institute building and was air-conditioned. Besides this, the bank had a few mobile collecting teams to bleed groups of donors at their places of work or at other convenient centres. These mobile teams operated throughout Bengal and worked in the city and its suburbs in factories, jails, tea gardens, camps and barracks all over the province. In bleeding a donor the limit of 500 cc. was not exceeded. The usual instruction was not to exceed 3 cc. to 3·5 cc. per pound of body-weight for Europeans and 2·5 cc. to 3 cc. for Indians. There was an adequate staff of doctors and nurses to carry out the work and an efficient propaganda section to enlist donors continuously.

All blood collected was immediately put into cold storage and the processing was done in special air-conditioned rooms within 72 hours of collection. The air of the processing chamber was 100 per cent. fresh and its bacterial content was minimal. The air of the chamber was tested periodically bacteriologically and maintained in a suitable state for ensuring safe processing. The processing work was done by the 'closed technique'. The bottles of filtered serum were stored at 4°C. Each bottle contained 500 cc. of filtered serum.

The 'adtevac' was used for drying liquid serum. Later the plasma drying 'desivac' also arrived from USA. Both were put into operation and with the help of these two machines, hundreds of bottles of liquid serum were converted into dry powder and issued. The

desiccated serum was readily soluble in water and on transfusion gave excellent results and no bad reactions.

Pyrogen-free distilled water was required in large amounts for reconstituting the desiccated serum. Arrangements were made to prepare this. The daily output was 100 litres. These were bottled in suitable amounts and sterilised and issued along with desiccated serum.

The table below gives the number of donors and quantity of blood processed from January 1942 to February 1945 :—

TABLE I

The number of donors and the quantity of blood processed from January 1942 *to February* 1945 *at the Calcutta Blood Bank.*

Number of donors	85,210
Amount of serum pooled and filtered ...	8,970,815 cc.
Liquid serum issued	11,442 bottles
Dried serum issued	6,920 bottles

The research section (under the professor of microbiology) attempted to obtain the blood proteins in a dry form by the use of simple chemical precipitation methods. Success was achieved and a suitable technique for large scale production was evolved. This product is now known as 'hardysed protein', as the method of precipitation that was adopted had been suggested by Hardy a few decades previously, though not practised.

It was found that some of the batches of processed serum did not give satisfactory results by the 'cat test'. Attempts were made to obtain the albumin in a pure state from it for use in transfusion according to Cohn's method. In connection with this, a new technique of electrodialysis was developed. This technique has been much commended for its simplicity and efficiency.[1] (Krishnan, Narayanan and Sankaran, 1944).

Hydrolysates of meat proteins were prepared for use as transfusion material by a new technique. This product was shown to be perfectly safe for intravenous administration. Though it was not as good as serum or plasma for combating shock, its value in the treatment of inanition and in a number of different surgical and medical conditions was fully established. Large quantities (25,000 bottles) were prepared and issued. It was admitted both by the civil and army authorities to be highly satisfactory. Protein hydrolysate as developed and standardised in the institute is now included in the Indian Pharmacopoeial list and is being used all over the world (Krishnan and Narayanan, 1944a, b).

[1] See also *Treatment and Management of Starving Sick Destitutes*, 1943, Calcutta: Manager, Government of India Press.

CONCLUSION

The foregoing account of the contributions made by the All India Institute of Hygiene and Public Health during World War II brings out clearly three points of importance which both the civil and military authorities may profitably note. The first is the truism stated by Prime Minister Jawaharlal Nehru in his autobiography "When bombs begin to burst, we may leap forward at a pace surprising to ourselves", has been substantiated by the account given. The dark and devastating global war gave a tremendous impetus to research in many fields of science and rendered great achievements possible. The second is that with the minimum dislocation of normal activities, war time work of an important nature can be undertaken by civilian institutions provided the right type of personnel are appointed to various posts in these institutions. Thirdly, even in peace time the future military requirements must be kept in view and certain civilian institutions must be earmarked as key institutions and properly equipped and staffed. Then and then alone, these institutions can profitably collaborate with the military at short notice and give them the technical help and direction that they may need when any emergency arises.

(ii) CENTRAL RESEARCH INSTITUTE, KASAULI

The supply of vaccines and sera for the armed forces in India was normally carried out through the Central Research Institute (CRI), Kasauli. The war time arrangements were an extension of the system of supply in operation in peace time.

In peace time the institute : (a) manufactured and issued all vaccines except plague vaccine required by the armed forces in India, (b) manufactured and issued all antivenene, and (c) received, stocked, and issued all imported therapeutic and prophylactic sera for armed forces.

Stocks of vaccines used for large scale inoculations were maintained for both military and civil issue at a level which by experience had been found to be adequate to meet demands, with appropriate reserve. A minimum figure had been fixed for the stock of TAB vaccine to be maintained. As civil demands for anticholera vaccine were liable to be very heavy at times, the stock maintained was always more than adequate to meet military requirements as well. The stocks of imported sera and vaccines held for the use of armed forces were obtained by monthly import and adjusted from time to time to a level which would be sufficient to meet four months average demands from military hospitals plus the quantities required for the mobilising medical units.

SITUATION AT THE OUTBREAK OF HOSTILITIES

Vaccines: The CRI manufactured prophylactic vaccines and issued them to military hospitals in India, to units on mobilisation, and to areas overseas for which India had been made responsible for such supplies. As the institute also manufactured vaccine for issue to civil

agencies, large stocks were always available. No difficulty was experienced in meeting such demands and production could be readily increased to meet emergencies.

The principal vaccines manufactured and supplied were :— TAB vaccine, anticholera vaccine, antirabic vaccine and stock curative vaccines.

Materials Required for Vaccine Production: The question of materials required in production and issue of vaccines had been considered before the outbreak of war and gaining from the experience of World War I, the necessity of having adequate reserves for manufacture was anticipated. A certain basis of minimum stocks had been fixed, for two or three years not only for the purpose of keeping war reserves but also for meeting the very heavy demands which might occur in the case of an epidemic outbreak of cholera. The stocks accordingly had to be large, and in September 1939, stocks of most items were at a level equivalent to about two years average requirements. The item in which difficulty in obtaining supplies could be anticipated was glass ampoules. In peace time those used at the CRI were of German origin or made from imported German glass tubing. The Government of India had sanctioned a special reserve of 1,80,000 ampoules of 20 cc. capacity and 36,000 of 1 cc. capacity for the purpose of providing for large issues in case of emergency and this reserve had always been maintained. A very large stock of vaccine ampoules equivalent to two years average requirements or more, apart from the quantity required under severe epidemic conditions, was in store at the CRI at the outbreak of war. Besides, indigenous sources of supply for these and other items in vaccine production had been found. Vaccine ampoules, made from neutral glass manufactured by a firm in Calcutta, were found to be in every way suitable. These passed BP test for limit of alkalinity and were well made exactly to the required shapes and sizes. As many other institutes were also drawing on the same source of supply, it was found necessary to ask for priority for the requirements of the CRI.

TAB Vaccine: The average annual peace time issues of TAB vaccine varied from 3,50,000 cc. to 4,00,000 cc. In peace time a stock of about 2,50,000 cc. was kept. Civil demands were small. The capacity for production at the institute was 1,00,000 cc. weekly without difficulty provided emergent manufacture of cholera vaccine on a large scale was not in progress. The production could be increased, if necessary.

Alcoholised Vaccine: The use of alcoholised TAB vaccine recommended by Felix (1941) was considered. The phenolised TAB vaccine had given very satisfactory results, and while the efficiency of alcoholised vaccine is not questioned, its introduction during the war would have amounted to 'a change of horse in mid-stream'. The whole question is open to review later when the alcoholised vaccine would have stood the test of time on a large scale.

Cholera Vaccine : Cholera vaccine was manufactured on a large scale mainly for civil use. No reserve stock had been laid down for

army use but the vaccine, in small quantities, was included in MME scales of medical units. Army requirements could be readily met from ordinary stock which was kept at a level of from 5,00,000 cc. to 10,00,000 cc. according to the time of the year. Production in emergency was possible at the rate of 2,00,000 cc. weekly, if necessary.

Mixed Influenza Vaccine : This was produced on a smaller scale and certain quantities were supplied to military hospitals. The vaccine was included in certain MME scales only up to the beginning of the war and was later deleted.

Curative Vaccines: Mixed catarrhal vaccines, *gonococcus* vaccine and mixed *gonococcus* vaccine were manufactured and supplied in small quantities to military hospitals and were included in some MME scales.

The position of reserve stocks of vaccines at the outbreak of war and the arrangements for supplies of material necessary for their continued manufacture ensured that there would be no difficulty in meeting any demand. It was considered that the capacity of the institute for production was in excess of any requirements for the forces in India, or overseas, which the institute might be called upon to meet.

Antivenene Sera: This was manufactured for both military and civil requirements but was mainly issued to the civil. The serum was included in certain MME scales and demands could readily be met from ordinary stock. A considerable reserve was maintained in the form of bulk concentrates.

Imported Sera: In peace time all sera required by the armed forces except antivenene, were purchased by contracts placed in London by the office of the High Commissioner for India (India Stores Department, London). These were received and stored at the CRI, Kasauli, on behalf of the Defence Department and issued in accordance with the instructions of the DMS in India. Supplies were adjusted in peace time, by the Director, CRI, in accordance with fluctuations in stocks depending on variations in demands, so as to maintain stocks equivalent to approximately four months average issues.

During 1939, under 'stock lag' system[2], arrangements were made to increase the stock to the equivalent of six months requirements. The additional supplies had not been received at the outbreak of war but arrived in successive consignments during the period October 1939 to January 1940.

Supply on Mobilisation: This was carried out under a contract between the Government of India and Messrs. Burroughs Wellcome & Co. In consideration of an annual payment, the firm undertook the responsibility to maintain stocks of certain sera which would be available immediately on telegraphic demand. The contract called for :—

(i) Immediate despatch of one supply by parcel post.

(ii) Immediate despatch of another supply by mail steamer.

(iii) Regular monthly supplies thereafter, the first to reach Kasauli five weeks after delivery of order in London.

[2] See Volume on *Administration*, page 338.

The telegraphic demand for the sera was despatched on 2 September, 1939. Supplies (i) and (ii) arrived together in November 1939 and the first supplies under (iii) arrived in December 1939 and continued at approximately monthly intervals thereafter.

The quantities of sera included in the schedule to the contract were as follows :—

TABLE II

The quantities of sera included in the contract with Messrs Burroughs Wellcome and Co.—1939.

Sera	Supplies		
	(i)	(ii)	(iii)
Tetanus antitoxin (500 AU = 1,000 IU) capsules	600	700	3,600
,, ,, (1,500 AU = 3,000 IU) capsules	860	1,910	2,400
,, ,, (8,000 AU =16,000 IU) or (10,000 AU =20,000 IU) capsules concentrated	110	430	100
Diphtheria antitoxin 10,000 units—capsules ...	54	195	300
Anti dysentery serum 8,000 units (Shiga) 25 cc. capsules or less	250	470	520
Antimeningococcus serum 10 cc. capsules concentrated =(30 cc.)	1,332	...	...
Antistreptococcus serum 10 cc. capsules ...	110	370	300
Antigas-gangrene serum 4,000 units (Welchii), capsules	110	370	200

AU = American unit. IU = International unit.

During the earlier period of war, the scales for field medical units were revised and among the points considered was the question whether certain sera were necessary in view of the efficacy of sulphonamides and their derivatives in the treatment of infections.

Antistreptococcus serum and antimeningococcus serum were thus removed from the scales for all medical units except depot medical stores in which a small quantity of each was provided.

In view of the unsettled position in regard to the relative value of sulphonamides and serum in the treatment of gas-gangrene, a considerable quantity of gas-gangrene serum was left in the scales for depot medical stores, where it could be drawn upon by units in accordance with local experience in fields of operations.

THE SUPPLY OF VACCINES AND SERA AFTER THE OUTBREAK OF WAR

Vaccines and Antivenene : The issue of the major products manufactured at the CRI namely TAB vaccine, cholera vaccine, antirabic vaccine and antivenom serum, during the period 1 July 1939 to 30 April 1946 is given in Table III.

TABLE III

Issue of major products manufactured at the CRI, Kasauli for military and civil use from 1 July 1939 to 30 April 1946.

Year	TAB vaccine cc.			Cholera vaccine cc.			Antirabic vaccine cc.			Antivenom serum 10 cc. ampoules		
	Military	Civil	Total	Military	Civil	Total	Military	Civil	Total	Military	Civil	Total
1939 (1 July to 31 December)	146,803	39,595	186,398	77,512	170,282	247,794	20,226	468,540	488,766	883	4,291	5,174
1940	499,480	96,805	596,285	174,892	673,867	848,759	102,692	2,241,700	2,344,392	2,472	5,395	7,867
1941	1,244,306	263,822	1,508,128	978,500	2,121,036	3,099,536	126,125	2,281,123	2,407,248	5,044	8,061	13,105
1942	1,907,167	202,094	2,109,261	1,776,097	1,055,548	2,831,645	164,747	2,169,336	2,334,083	9,441	8,044	17,485
1943	3,030,564	167,961	3,198,525	3,637,881	1,589,094	5,226,975	238,292	2,313,368	2,551,660	12,839	7,572	20,411
1944	3,870,840½	293,720½	4,164,561	3,228,939½	1,808,456½	5,037,396	309,637	2,471,984	2,781,021	14,409	8,746	23,155
1945	4,918,630	269,078½	5,187,708½	3,214,625	572,524½	3,787,149½	439,709	2,314,094	2,753,803	18,916	8,583	27,499
1946 (1 January to 30 April)	1,082,904	154,430	1,237,334	1,441,872	59,629	1,501,501	176,412	1,073,256	1,249,668	1,662	1,718	3,380
Total	16,700,694½	1,487,506	18,118,200½	14,530,318	8,050,437	22,580,755½	1,577,240	15,333,401	16,910,641	65,666	52,410	118,076

The issue of a record figure of 12 million cc. of vaccine in 1944 was the highest in the history of the institute. TAB and cholera vaccines were mainly issued to military indentors whereas antirabic vaccine was mainly issued to civil. The progressive increase in the rate of issue is best shown by the issues of TAB vaccine which was not affected by the prevalence of any epidemic condition as in case of cholera vaccine.

The approximate monthly production capacity of the institute was about 900,000 cc. of vaccine. In the earlier years of war (1939-41), stocks in hand together with the production at the institute were sufficient for all requirements. The reserve stock of TAB vaccine normally kept was increased to 500,000 cc. Anticholera vaccine reserves were increased to a figure between 500,000 cc. to 1,000,000 cc. according to the time of the year. By October 1942, the reserve was increased to 1,500,000 cc. with 300,000 cc. ampoules.

In later years of the war, the demands and issues sometimes exceeded the maximum production capacity of the institute and were largely met from reserve stocks. In February 1944, the question of expansion of the CRI was raised as it had reached its target of maximum output of vaccine possible with the existing resources. In August 1944, a total issue of 1,868,710 cc. of the three major vaccines were made. This was the maximum issue in one month in CRI's history and approximately represented double the maximum production capacity. The demands could be fully met owing to large reserve stock accumulated as a result of continued manufacture at full pressure throughout the year. The second highest issue in one month was in April 1945 when 1,484,152 cc. were issued. Demands in September 1944 were also very high—1,200,000 cc. of cholera vaccine alone being indented. The military demands were met in full but owing to depletion of reserve stocks due to high issues in the previous month, civil demands could not be met and an indent for 688,400 cc. was passed to the Public Health Commissioner with the Government of India so as to arrange supplies from reserves held on his behalf at other centres.

The record output of about 12,000,000 cc. of vaccine in 1944 was possible only by working overtime at full pressure throughout the year. It necessitated sacrifice of Sundays and other holidays. There were constant anxieties over supply of fuel for boilers, kerosene oil for gas plant, glassware, sheep for antirabic vaccine and a number of other essential items. There was constant fear of failure of essential plant, apparatus and equipment which included the very old and overworked sterilising plant. Fortunately, however, no serious breakdown occurred and all demands were met in 1944 except the civil indents in September.

The highest demands in the history of the CRI were made in February and March 1945, when 2,782,422 cc. and 3,357,869 cc. respectively were indented. Obviously these demands could not be met as they represented more than three times the maximum production capacity of the institute. This was the first occasion on which military indents could not be met from stocks. The largest demand of 2 million

cc. of cholera vaccine was made by the DMS in India for Civil Affairs Services, Burma.

The whole subject of supply of vaccine and sera was discussed at a meeting of the Army Pathology Advisory Committee (India), held at GHQ on 27 February 1945. It became apparent during the discussions that the CRI would be capable of producing sufficient quantities of vaccine for use of military personnel, both in the India Command and the SEAC provided reasonable economy was exercised in their use. It was, however, not possible to meet demands of vaccines for the protection of the civil population coming under military administration.

On the recommendations of the committee, the DMS in India issued a special appeal and requested the DMS, ALFSEA to take similar action. The following decisions were reached :—

(i) All biological products were to be placed on controlled list of items in military medical stores.

(ii) Director, CRI was to comply normally with all reasonable military indents.

(iii) If indents for any particular vaccine was abnormally high, Director, CRI was to issue a proportion of it only and refer the indent to GHQ for instructions regarding the outstanding balance.

(iv) Manufacture of TAB vaccine was to be given precedence over that of cholera vaccine.

There was another meeting of the Army Pathology Advisory Committee on 30 April 1945, and a decision was reached to approach the Public Health Commissioner with the Government of India for supplies. The latter undertook to meet all civil demands from other sources but was unable to foresee that additional military supplies could be made available from these sources. He, however, agreed to make available to the army, quantities that were surplus to civil requirements.

Since demands exceeded maximum output of the CRI and the scheme for increased production was not likely to materialise, it became increasingly necessary to plan the disposal of available products in the best possible way. After discussion with military and civil authorities the following arrangements were completed in May 1945 :—

> The institute undertook to manufacture 4,000,000 cc. of TAB vaccine for the Defence Services. Of this quantity 2,500,000 cc. were required by the India Command and the remaining 1,500,000 cc. for ALFSEA and through them for Civil Affairs Services (Burma). To meet the latter demand, 125,000 cc. were to be issued each month to No. 36 Indian Base Medical Stores, Panagarh. The institute also undertook to supply a guaranteed minimum of 3,000,000 cc. of cholera vaccine a year for the Defence Services. A special reserve of 100,000 cc. was held on behalf of the DMS and issues to the India Command were only to be made when stocks in excess of this reserve were available. As regards supply of cholera vaccine to ALFSEA, demands for 289,500 cc. were accepted for the period May to October 1945. It was decided that priority would be given to military demands and issues would be made depending on stocks. It was, however, found necessary to pass all large indents from civil sources to the Public Health Commissioner with the Government of India for arranging supply from reserves held at other centres.

The effects of these arrangements were already apparent in June 1945. It was possible to meet more than the guaranteed minimum of military demands and in addition some civil demands too.

In January 1946, total issues of vaccine again went up to more than the maximum production capacity for the CRI. This rise was partly due to a standing order for 200,000 cc. of cholera vaccine and 125,000 cc. of TAB vaccine monthly for ALFSEA and a further demand for a reserve for ALFSEA of 600,000 cc. of cholera vaccine and 300,000 cc. of TAB vaccine. The latter reserve was being built up by an issue of 100,000 cc. of each vaccine monthly as far as possible.

TAB Vaccine : In the first half of 1941, the issues of TAB vaccine were at a level approximating four times the average pre-war rate of issue, in spite of the fact that the dose for re-inoculation had been reduced from 1·0 cc. to 0·5 cc.

An inquiry as to whether supply of TAB and cholera vaccines from India would be required for forces in the Middle East area was put through by the DGIMS. It was intimated that these vaccines would not be required but at the end of July 1941, a supply of 6,000 cc. of TAB vaccine was demanded. A further demand of 50,000 cc. of TAB vaccine was received from the Middle East in August 1941, and was sent by air. On 28 September 1941, there was a meeting of a sub-committee in Simla, which considered the question of the supply of vaccine and sera to areas under the Eastern Group Supply Council. There was a demand of 750,000 cc. of TAB vaccine and 500,000 cc. of cholera vaccine from Middle East for a period of nine months from 1 April 1941. Forces in Malaya demanded 60,000 cc. of TAB vaccine and 50,000 cc. of cholera vaccine as bulk and one-sixth of the quantity monthly thereafter. The decision reached by the sub-committee was that no action would be taken until a firm demand was placed.

There was a fairly steady rise in the issues of TAB vaccine in 1942 and manufacture had to be continued at a high level to maintain and replace stocks and to increase reserves. Demands continued at a steady level between 200,000 cc. and 250,000 cc. a month and stocks had to be increased to 1 million cc. including 200,000 cc. ampoules ready for issue. Of demands for TAB vaccine, 90 per cent. were for military use.

In 1943, issues increased ten times compared to pre-war level. As there was no increase in staff, this involved continuous work at full capacity so that production could keep pace with demands. Towards the end of the year, there was a drop in issues of both TAB and cholera vaccines, and reserves which had been depleted by previous heavy issues were built up.

In May 1944, the Director, CRI drew the attention of the DMS to alcoholised TAB vaccine prepared according to Felix's method which was in use in the United Kingdom but expressed the opinion that it would be unwise for the Army in India to follow that lead until it was found to be superior to heat-killed phenolised TAB vaccine. The matter was referred to the Army Pathology Advisory Committee (India).

The committee advised the DMS to adhere to the existing vaccine on the basis of exceptionally low incidence of enteric group of fevers in spite of a falling off in the standards of hygiene which was apparent from a definite increase in dysentery and other bowel disorders.

Before the introduction of prophylactic inoculation with TAB vaccine, typhoid group of fevers presented a serious problem to the army in peace and war. The incidence of enteric fevers in the Army in India was in the neighbourhood of 40 per 1,000 per annum. Since World War I, TAB inoculation has been carried out as a routine measure in the armed forces in India and in 1939 before the outbreak of World War II the incidence was 1·1 per 1,000 per annum. As is well known, circumstances prevailing in wai time greatly favour the spread of bowel diseases, especially in tropical countries. This is well brought out by the high incidence of dysentery and diarrhoea—131·4 per 1,000 in the Armed Forces in India in the year 1944. One would reasonably expect a very similar rise in the incidence of typhoid group of fevers. Suppose a tenfold increase had occurred and assuming that the strength of the Army in India was, 2,000,000 in five years of war, this would have resulted in 110,000 cases of enteric fevers. The strain on the medical and nursing services can be well imagined had they been called upon to look after 110,000 cases of typhoid. In actual fact the incidence of typhoid fevers in the Army in India was well below 0·5 per 1,000. This can only be attributed to the efficacy of the TAB vaccine prepared at this institute. That the army authorities fully appreciate this is shown by the following extract taken from the Annual Report of the Health of the Army in India for 1944 :—

> "That only 12 British soldiers in every 10,000 contracted a fever of the enteric group in a year like 1944, with the Japanese forces at the gates of India, with large numbers of unacclimatised troops, with intensive training going on in camps situated amongst civil populations among whom the disease was rife and with water supplies stretched to breaking point, is considered to be a remarkable testimony to the efficacy of preventive inoculation with TAB vaccine. This low incidence of what even fifty years ago was one of the principal diseases among the members of the British Army in India cannot be ascribed to any revolutionary improvement in sanitation since sanitation in 1944 was in fact considerably less efficient than in 1939 or in the decade preceding 1939 ; it can only be ascribed to a high rate of protection by an efficacious vaccine. This claim is strengthened by the fact that the dysentery-diarrhoea group of diseases, for which no vaccine exists, have, over the period in which the enteric fevers have been declining, steadily increased, their rate for 1944 being treble the average rate for the decade 1929-38. The TAB vaccine used in India is prepared by the Central Research Institute, Kasauli, and is a heat-killed phenolised vaccine ".

Cholera Vaccine : The CRI was heavily pressed for manufacture of this vaccine during June, July and August 1941, owing to an epidemic of cholera which necessitated its production in large quantities. The prevalence of cholera in Northern India continued to be abnormal and even in October 1941 apparently epidemic conditions prevailed in the North-West Frontier Province, Swat and Kashmir and also in Assam,

necessitating an issue of 583,978 cc. of cholera vaccine, compared to an average issue of 15,000 cc. for the month for the previous seven years.

In January 1942, 20,000 cc. of cholera vaccine was issued to the Director of Public Health, Central Provinces, though the CRI was not normally supposed to meet such demands.

In February 1942, the stock of cholera vaccine was raised to more than one million cc. in the form of concentrates with 140,000 ampoules ready for issue, in anticipation of heavy demands on account of conditions in Burma and the possible risk of introduction of infection into Assam and Bengal, though these areas were not normally served by the CRI. Large quantities had to be issued to Burma in March 1942, owing to cessation of manufacture there and also to Assam and Bengal, necessitated by the influx of refugees by road to Assam and for labour parties engaged on road construction, etc. Military demands were chiefly from Bengal and Southern India. Demands decreased in April 1942, but issues were considerable in relation to normal experience. Issues for the first three months of 1942, already formed a larger total than that of an average year when cholera was epidemic. Demands continued to be high in May 1942, owing to precautionary measures taken in the army and certain amount being sent overseas. In June 1942, there was a fall in demands at a time when increase was usual due to absence of any epidemic and this afforded an opportunity to build up stocks. A bulk quantity was issued to military indentors in July 1942, but a heavy civil demand from the Central Provinces was passed to other institutes under arrangements made by the Public Health Commissioner with the Government of India. Military demands continued to be high in August 1942, presumably due to routine inoculations. A large quantity of cholera vaccine was sent to military indentors in South India in November 1942, where considerable prevalence of cholera was reported.

In February 1943, one supply of 80,000 cc. of cholera vaccine was made (lease-lend) to China. In March 1943, 10,000 cc. of the vaccine was supplied to the US forces.

The total military issue of cholera vaccine in May and June 1943 amounted to 940,000 cc. If demands continued at this level, it was considered that considerable expansion of plant and staff of the institute would be necessary to meet the situation. The large military issues during May-July 1943 were due to an incidence of cholera in Northern India.

In November 1943, civil issues were very high owing to an outbreak of cholera in Kashmir (130,000 cc. issued) and a special demand of 250,000 cc. from Bengal. A scheme of large scale inoculation, with a total of nine million doses as the objective, was undertaken in Bengal to prevent epidemic conditions prevailing as an aftermath of Bengal famine. Though Bengal was not normally served by CRI, resources of all institutes in India had to be mobilised for this stupendous task. After the initial bulk supply of 250,000 cc., a weekly supply of 100,000 cc. or more, if available, was required to be sent to Bengal.

Additional supplies of glass ampoules and agar were received and manufacture continued at maximum level possible to meet likely demands from Bengal. The possibility of increasing greatly the production was limited by the capacity of boilers and sterilising plant. Considerable experimental work was undertaken to obtain the highest yield per bottle. The highest issue was in December 1943, when 400,000 cc. were sent to Bengal, while normally issue should be lowest in this month. In January 1944, 200,000 cc. of cholera vaccine were supplied to Bengal. By March 1944, a total of 1,000,000 cc. of cholera vaccine had been supplied to Bengal since November 1943, and this was considered sufficient for existing needs.

At the beginning of 1944, it was arranged that supply of cholera vaccine for military units in certain areas of South India would be undertaken by the Haffkine Institute, Bombay, thus relieving the CRI to some extent. In April and May 1944, the issues of cholera vaccine were considerably below the recent monthly averages and total issues were also correspondingly less. It was possible to build up a much more satisfactory reserve and replenish stocks seriously depleted, as manufacture at the CRI continued at full production capacity.

In July 1944, a report was received from Delhi of delayed reactions occurring a week after cholera inoculation. It consisted of local redness, swelling, pain and febrile reactions lasting for 48 hours. Similar reports had been received in the past but it was not possible to correlate this with any variations in technique. Probably the reaction was analogous to serum sickness.

There was an excessively high issue of 1,222,333 cc. of cholera vaccine in August 1944 and 585,438 cc. in September 1944. Of these, military issues were 449,519 cc. and 242,792 cc. respectively and all military demands were fully met. Issues declined in October 1944, and appreciably so in November 1944, when a part of the depleted reserve stock was replenished.

It was estimated in January 1945, that sufficient quantities of cholera vaccine had been issued to inoculate the entire army, though it was never the policy to attempt any such measure.

The first occasion, on which military demands for cholera vaccine could not be met, was in February 1945, when a quantity of 791,000 cc. remained outstanding. Similarly in March 1945, 2,213,125 cc. of cholera vaccine could not be issued to military indentors (2 million cc. indented for Civil Affairs Services, Burma). During May-August 1945, demands considerably exceeded supplies but all military indents were met to an extent more than the guaranteed minimum, under the new arrangements made in May 1945.

In August 1945, indents for large quantities of cholera vaccine for civil use were passed to the Public Health Commissioner with the Government of India. In September and October 1945, there was a sharp fall in the issues, and all demands, civil and military, were met in full.

Antirabic Vaccine : These vaccines were mainly issued to civil indentors and showed general upward tendency in issues during the war year though it varied from month to month. The military issue formed only a small part of the total issues. At an earlier period of the war antirabic vaccine was included in the supplies for Middle East and Iraq. It was understood that this vaccine was available locally in Iraq and Egypt and also in Malaya. A medical officer from Iraq had been trained at the CRI in the manufacture of antirabic vaccine. It was, therefore, considered that the supply of antirabic vaccine to these countries was unnecessary and that local procurement should be resorted to.

The continued rise in demand for antirabic vaccine caused anxiety as to whether it would be possible to meet all requirements. Production was impaired in November 1942, due to high pre-passage rate of mortality among the sheep imported from plains. It was as high as 20 to 30 per cent. No specific cause could be found for this high mortality except feeding conditions during the monsoon. During this year approximately 2,500 sheep were used. There was difficulty in getting enough sheep and the prices were rising. The administrative medical officers were requested to exercise strict control on the use of this vaccine as it was understood that many persons were being treated with antirabic vaccine unnecessarily.

The first contract, in the financial year beginning from April 1943, to get supply of enough sheep failed. It was cancelled and the second contract at a higher rate was made and an adequate number of sheep were obtained and stock of antirabic vaccine was brought to a safe level.

In January 1946, 320,083 cc. of antirabic vaccine were issued. This was partly due to certain issues to Rangoon necessitated by the occupation of Burma. A record issue of 346,197 cc. of antirabic vaccine was made in February 1946. In March 1946, the issue of antirabic vaccine still continued to be high.

Antivenom Serum : The number of horses under immunisation for antivenom production was raised from 10 to 20 in March 1942. By April 1942, there was no large reserve stock of antivenene available and demands continued to be high. In August 1942, the issue of antivenene was greater than production. A request to send supplies of antivenene to Egypt and other areas was considered in relation to the stocks available and the rate of production. In October 1942, some stock could be built up due to lower rate of issues. Some difficulty was encountered in obtaining supplies of ammonium sulphate for use in the concentration and it was necessary to purify some supplies before use. The issue of antivenene in December 1942 was lowest in the year. Military issues of antivenene increased sevenfold in 1942 but the CRI could meet all demands without the corresponding increase in its staff. By April 1943, a satisfactory stock of antivenene was built up for the ensuing season. The manufacture of antivenene continued at as high a level as possible during October 1943. The position as regards horses was not satisfactory due to loss of several animals. Hence additional horses were asked for from the Remount Depot and put under immunisation for production of antivenene.

Typhus Vaccine : A supply of vaccine (X19 Cox's type) amounting to 30,100 cc. was received for the Local Provision Office stock. Instructions were received from the DMS that this vaccine was to be issued only in special circumstances on his authority.

The demands were very small and in March 1944, only 1,120 cc. were indented. By June 1944, the original stock of typhus vaccine was near its last date of expiry but fresh supplies were received in large quantities. In July 1944, 114,000 cc. was received and the original time-expired stock was written off.

In October 1944, the attention of ADP, GHQ was drawn to the fact that all existing stocks would become time-expired early in 1945. In December 1944, instructions were received that the stocks had been given a further lease of six months as there was no loss of potency in one year.

In March 1945, a stock of 50,000 cc. of typhus vaccine were earmarked for civil use. Of these 10,000 cc. were issued to the Government of Kashmir. In March 1945, civil supplies earmarked for the Kashmir Government arrived and the quantity previously borrowed from the Local Provision Office stock was replaced. By May 1945, the stock of typhus vaccine, held on behalf of the DMS, was nearing its last date of expiry. Arrangements were made with the DGIMS to make available for military use the stocks held at the CRI.

In June 1945, instructions were received not to write off the DMS's stock of typhus vaccine pending an inquiry whether further extension was possible. The CRI was informed in October 1945, that the time-expired typhus vaccine stock was no longer of declared potency. Small issues were made to military indentors from DGIMS stocks.

As no fresh supply of Cox's vaccine was received by June 1946, demands both from civil and military could not be met. In February 1946, a supply of typhus vaccine of Canadian manufacture was received. The last date of expiry was two years from the date of manufacture provided storage conditions were satisfactory.

In March 1946, a stock of typhus vaccine, held on behalf of Public Health Commissioner with the Government of India and Kashmir Government, became time-expired.

Imported Sera and Tetanus Toxoid: The issue of imported sera and tetanus toxoid for military use during the years 1939-45 is indicated in Table IV.

Imported Sera: By April 1940, large stocks had accumulated and it was decided to suspend import from the United Kingdom for six months. The import was not resumed in October 1940, but instead, orders were placed in Australia and the following items arrived from the Commonwealth Laboratories, Melbourne, between October 1940 and January 1941.

Items	Tubes
Tetanus antitoxin 3,000 IU ...	50,000
Diphtheria antitoxin 10,000 units ...	6,000
Antidysentery serum, polyvalent ...	2,004

TABLE IV

Issues of sera and tetanus toxoid for military use (ampoules, doses or cc.).

Product	1 July 1939 to 31 December 1939	1940	1941	1942	1943	1944	1945
Diphtheria antitoxin 5,000/10,000 units, ampoules	1,393	4,558	7,111	15,181	13,375	18,417	64,909
Tetanus antitoxin 500 AU, ampoules	8,672	17,366	14,283	14,320	8,211	...	...
Tetanus antitoxin 1,500 AU, doses	14,743	25,192	65,146	191,195	327,134	297,425	605,266
Tetanus antitoxin 8,000/10,000 units, ampoules	208	2,737	4,318	10,392	12,260	10,004	2,092
Antistreptococcus serum, 10 cc. ampoules	1,312	1,115	2,806	748	740	21	...
Antimeningococcus serum, ampoules	1,249	2,280	2,270	1,554	616	48	...
Antidysentery serum 8,000/25,000 Shiga units, ampoules ...	2,657	7,088	10,949	27,765	17,206	11,878	15,266
Antigas-gangrene serum, ampoules	981	3,356	3,955	20,921	54,023	...	...
Antigas-gangrene serum polyvalent prophylactic, doses ...	...	...	...	...	...	41,195	130,862
Antigas-gangrene serum therapeutic, ampoules	...	...	...	...	...	21,758	9,735
Antianthrax serum, ampoules	...	...	...	...	...	1,204	1,630
Tetanus toxoid, cc.	...	260,770	568,441	701,782	2,419,861	3,574,290	4,022,970

Under these conditions, supplies were ample with the exception of two items, viz., tetanus antitoxin 16,000 IU for therapeutic use and antigas-gangrene serum.

Australia appeared to be a convenient source of supply during the emergency since one particular consignment despatched by air from Sydney arrived in Gwalior in a period of eight days only.

Orders had been placed by cable in the United Kingdom on 11 December 1940, by the DGIMS, for quantities of sera to cover a considerable period on the basis of a recalculation of commitments. As, however, no supplies arrived from the United Kingdom till November 1941, considerable difficulty was experienced due to complete exhaustion of stocks of tetanus antitoxin, antidysentery serum and antigas-gangrene serum during the period March to June 1941. The likely shortage of antitetanic serum had been foreseen at a meeting of the Drugs Supply Committee held at New Delhi on 21 October 1940, and it was agreed that purchase should be made from indigenous sources.

Sera manufactured in India had not been purchased for the use of armed forces so far, but as the result of an inspection of the conditions of manufacture of one of the firms in Calcutta (Bengal Immunity Co.), it was decided to place an order for 1,000 tubes of tetanus antitoxin (20,000 IU) under arrangements for control of potency and sterility tests which were to be carried out by the CRI and District Laboratory, Calcutta. This supply was received by the end of June 1941, and was found to be satisfactory.

In view of the likelihood of shortage, a telegraphic demand was made on the United Kingdom on 27 March 1941 for despatch by air and the order was duplicated on Australia. The order for antidysentery serum on the United Kingdom was transferred to the USA and a supply was received at Kasauli on 28 June 1941. Supplies of polyvalent antidysentery serum, antigas-gangrene serum and tetanus antitoxin arrived from Australia on 25 June 1941. These supplies enabled outstanding demands to be cleared but did not leave an adequate reserve.

The principal factor affecting supplies was the non-arrival of the sera due under the orders dated 11 December 1940, placed in the United Kingdom. From a cabled inquiry in June 1941, it was learnt that 58,250 ampoules of 1,500 AU tetanus antitoxin and half the quantity of antidysentery serum included in the indent were under shipment from New York ; antidiphtheritic serum awaited shipment ; and no order had been placed for antigas-gangrene serum.

To meet shortage of antigas-gangrene serum, orders were placed in August 1941 with the Eastern Group Supply Council for fulfilment either in Australia or South Africa. Meanwhile, as a stop-gap, orders were placed with the Bengal Immunity Co. for supply of 1,000 tubes of antigas-gangrene serum containing 4,000 perfringens units. A sample from the bulk showed on testing 650 units per cc. and hence 8 cc. ampoules were asked for. Orders were also placed on the

same firm for supply of tetanus antitoxin 10,000 AU and diphtheria antitoxin 10,000 units (2,000 tubes each), subject to the same control for potency and sterility by the CRI and the District Laboratory, Calcutta.

Antigas-Gangrene Serum : Stocks of antigas-gangrene serum were exhausted in September 1941. In October 1941, 342 tubes of 4,000 perfringens units from Bengal Immunity Co., Calcutta and 1,000 tubes of polyvalent gas-gangrene antitoxin from South Africa were received. It had been decided at a meeting of the sub-committee for vaccines and sera that polyvalent gas-gangrene serum was desirable. In February 1942, 2,940 ampoules of polyvalent therapeutic antigas-gangrene serum were received. By June 1942, stocks became low again. Regular imports in the latter half of 1942 and 1943, however, enabled the CRI to meet all demands. By April 1944, stocks of antigas-gangrene serum (therapeutic) were completely exhausted and this serious shortage continued till July 1945. The attention of the DMS had been drawn to this shortage in July 1944, as demands could not be met. By August 1944, even the stocks of antigas-gangrene serum (prophylactic) were exhausted. At a meeting of the Army Pathology Advisory Committee held at GHQ on 27 October 1944, it was decided that stocks of antitoxin gas-gangrene monovalent (Welchii) should be taken on charge and issued for prophylactic use pending receipt of suitable polyvalent serum in adequate quantities. In November 1944, and again in January, March and April 1945, small supplies of prophylactic antigas-gangrene serum (polyvalent) were received but they were quickly exhausted and there was no antigas-gangrene serum (therapeutic) available for issue. In May 1945, all receipts of antitoxin gas-gangrene were immediately forwarded to No. 36 Indian Base Medical Stores, Panagarh. The position regarding antigas-gangrene serum improved in July 1945 when large consignments arrived by air-freight from the United Kingdom.

Diphtheria Antitoxin : The manufacture of diphtheria antitoxin was undertaken at the CRI itself in August 1941, and a bulk stock equivalent to 2,000 tubes was accumulated. By January 1942, 1,800 tubes of 10,000 units were in sight. In March 1942, manufacture of diphtheria antitoxin at the CRI slowed down as all available horses except two were turned on antivenene production, the demands for which were heavy. In June 1942, bulk concentrates were stored and a stock of 1,400 ampoules was maintained. As imported supplies also started coming in, diphtheria antitoxin was available in adequate quantities in August 1942, in the form of concentrated and preserved unconcentrated serum. The stock of 1,500 ampoules was not drawn upon and thus a large reserve for emergencies could be built. In November 1942, the manufacture of diphtheria antitoxin at the CRI was suspended since stocks were sufficient. In May 1943, the stocks of diphtheria antitoxin in hand were pooled up with reserve concentrates of high titre to bring up to full potency. In June 1943, stocks were increased by 504 ampoules of 10,000 units of CRI manufacture.

In December 1943, diphtheria antitoxin 10,000 units was in short supply. In January 1944, 693 ampoules were prepared from concentrates

manufactured at the CRI and taken on charge for military issues on account of the acute shortage. In February 1944, a large consignment arrived and the acute shortage experienced was relieved. After this, regular imports of diphtheria antitoxin continued and no further difficulty was experienced.

Tetanus Antitoxin : In September 1941, the stock of tetanus antitoxin amounted to only one month's issue. In October 1941, 1,005 tubes of 10,000 AU manufactured by Bengal Immunity Co., Calcutta, and 58,250 tubes of 1,500 AU from the USA were received. Supplies also arrived from the United Kingdom (Messrs. Burroughs Wellcome and Co. in November 1941 and Messrs. Evans Lescher and Webb in February 1942).

Tetanus antitoxin 500 AU was imported at a lower rate in 1942 than previously and issues diminished proportionately. Tetanus antitoxin manufactured by Bengal Immunity Co., Calcutta, passed full control tests at CRI and the product was found to be satisfactory.

In 1943, tetanus antitoxin 1,500 AU was a major issue. In spite of this, it was found by June 1943, that the issue of tetanus antitoxin 1,500 AU had not been in proportion to stock, and it was apprehended that a considerable quantity may become time-expired. In August 1943, tetanus antitoxin 8,000 or 10,000 AU was completely exhausted from Local Provision Office stock (Defence Department). Bottles containing ten prophylactic doses of 1,500 units tetanus antitoxin in a volume of 5 cc. were issued in place of tetanus antitoxin 10,000 AU for therapeutic purposes. Supplies, however, arrived in September 1943, and continued regularly after that.

A large stock of time-expired tetanus antitoxin was withdrawn from regular stock in June 1944 and kept as a special reserve for emergency. No further difficulty in supply of tetanus antitoxin was experienced till August 1945, when the stock for therapeutic use was practically exhausted. Adequate stock of concentrated tetanus antitoxin, designed for prophylactic use was, however, available for issue in lieu. Supplies of tetanus antitoxin 10,000 AU arrived in September and October 1945.

Antidysentery Serum: The first serious shortage was felt in February 1944 when stocks became completely exhausted. However, 3,340 ampoules of 10,000 units arrived to relieve the situation. The stocks continued to be at a low level in April 1944. Adequate supplies of antidysentery serum arrived in September 1944, when all demands were met in full. No further difficulty was experienced.

Antianthrax Serum: This was received from the Imperial Institute for Veterinary Research at Mukteswar. In September 1941, 402 tubes of 10 cc. volume were received. There was no stock in hand in July 1943. A monthly supply of 12 ampoules was being received to meet special overseas demands. A bulk supply of 1,035 ampoules in February 1944 and another of 1,503 ampoules in March 1944 were received to replenish the depleted stocks.

Tetanus Toxoid: Large quantities of tetanus toxoid were imported from the United Kingdom and Australia during the war years as indicated below :—

TABLE V

Tetanus toxoid imported from the United Kingdom and Australia.

Years	cc.
1940	416,530
1941	428,950
1942	1,426,980
1943	2,350,430
1944	4,689,410
1945	5,028,710

Issues were heavy early in 1941 and stocks were exhausted by March 1941. A consignment arrived on 18 March 1941, but was immediately issued to meet outstanding demands. By 20 May 1941, the outstanding demands, which could not be met, amounted to over 100,000 cc. As considerable delay was likely to occur in imports from the United Kingdom, arrangements were made to get the necessary supplies from Australia. The first consignment of 30,000 cc. arrived by air from Australia in May 1941, and was issued at once. Further supplies of 60,000 cc. in June and 24,000 cc. in July 1941, were received but were expended at once without having any reserve. Supplies came in regularly in the last four months of 1941.

In 1942, there was a shortage in the earlier part of the year but large supplies arrived subsequently. A supply was received from Australia in July 1942, in which the formalin used was not neutralised and no phenol was added. Special instructions were received for using this batch of toxoid and the attention of Medical Directorate, GHQ was drawn to this fact.

In March 1943, certain stocks supplied by Messrs Burroughs Wellcome and Co. showed deposit or deposit and cloudiness. It was ascertained from the manufacturers that those showing only minor degrees of deposit were fit for issue. The Australian product, in which formalin was not neutralised and no phenol added, however, remained clear.

In August 1943, a fuller report was received from Messrs Burroughs Wellcome and Co. on the samples sent to them from the batch showing cloudiness and precipitates. There was no loss of antigenicity and unitages were above the limits laid down in *Therapeutic Substances Regulations*. Hence the whole stock was considered fit for issue regardless of precipitate or cloudiness.

By July 1944, storage presented a problem as stocks amounted to approximately one and a half million cc. As this put considerable strain on the available accommodation, the DMS was asked in August 1944 to arrange for issues to armies/commands to relieve the storage problem.

MISCELLANEOUS ACTIVITIES OF CRI

Dyes

The following dyes, purified from crude imported products were tested and reported to be suitable for use as bacteriological stains.

Magenta (Substitute for Basic Fuchsin): This was found suitable as a general stain for bacteria as well as for selective staining of tubercle bacillus.

Chrysoidin: This was found suitable as counter-stain for *C. diphtheriae.*

Methyl Violet 2 BS: This was found suitable as a substitute for methyl violet 6 B for use in Gram's staining.

The following dyes of Indian manufacture were tested and accepted.

Eosin : This was prepared under arrangements made by Director of Production (Drugs and Dressings) from fluorescein manufactured in India for ophthalmological use. The first batch was found insoluble in water or alcohol but a subsequent batch proved satisfactory as a tissue counter-stain. Wright's stain was prepared with it at CRI in combination with an imported zinc-free methylene blue and the result was very satisfactory.

Methylene Blue : A sample manufactured in Delhi, stated to be zinc-free, was found to be satisfactory in staining power and in every way suitable for bacteriological purpose.

Leishman's Stain: A sample manufactured in Madras was submitted for test in two batches. One batch was found to be an excellent stain but the other batch was deficient in staining qualities and did not differentiate the chromatin satisfactorily. In March 1942, another batch of Leishman's stain manufactured in India was accepted after examination. It was decided in May 1942, that manufacture of Leishman's stain would be undertaken at the CRI when commercial supplies of the crude drugs, viz., methylene blue and eosin were available. In August 1942, a demand for 300 tubes, 5 g. each, was nearly completed. Samples from the bulk were tested at the Malaria Institute of India and found satisfactory. In November 1942, the first large demand for Leishman's stain had to be met from Local Purchase Office stock. Manufacture of azure II-eosin was also attempted and found satisfactory for preparation of Giemsa's stain. In September 1943, tests were carried out on stains for bacteriological purposes prepared from crude dyes by the industrial planning officer. Samples of chrysoidin, fuchsin, eosin and brilliant green were found to be satisfactory.

The following were tested for bactericidal action :—

Acriflavine: Samples of Indian manufacture was tested by methods employed by Browning and Gulbrausen. The sample was found to be satisfactory and compared favourably with acriflavine imported from U.K.

Methyl Violet: Methyl violet of Indian manufacture was tested in October and November 1941 in order to replace gentian violet in

surgery. The results were satisfactory and the dye was almost qualitatively equivalent to the imported Grubler's gentian voilet.

Brilliant Green : A sample purified from imported crude product showed bacteriostatic action of standard level. Disinfectants for use by different departments of the Government of India were tested at the CRI by Rideal Walker method. A large number of disinfectants were tested by this method in September 1943 on behalf of the Supply Department.

Peptone: Three samples of different origins (Indian manufacture) were tested. Two were found satisfactory for general purposes but inhibited in some degree the growth of certain organism such as *B. dysenteriae* Shiga. The inhibitory factor was found to be a peroxidase. However, *B. typhosus* and Flexner's strains grew well on media prepared with the same peptone.

Sodium Taurocholate : A sample of Indian manufacture was found suitable for bacteriological purposes.

Sterile Solutions for Parenteral Injections: In August 1941, the Director, CRI inspected firms in Calcutta in order to investigate the conditions of manufacture of ampoules of sterile solutions for parenteral injections with a view to placing orders on behalf of medical store depots. These conditions were approved only in case of Bengal Immunity Co., and Messrs. Smith Stanistreet and Co. It was arranged that sterility tests would be done locally by the officer-in-charge, District Laboratory, Calcutta, under the instructions of the Director CRI. In October and December 1941, sample sterility tests were done at CRI on ampoules purchased by medical store depots (morphia, adrenaline, quinine, pituitary extract, bismuth and camphor preparations, etc.). All samples were satisfactory. In February 1942, Director, CRI, visited Cipla and TCF in Bombay and Hind Chemical Works in Kanpur for inspection of the conditions of manufacture. The publication of *Instructions for manufacture of solutions for parenteral injections,* along with a formulary for special products included in the PVMS was undertaken at the CRI for the guidance of manufacturers. The question of suitable methods of carrying out sterility tests on certain ampouled products was investigated.

GLASSWARE

Ampoules for Vaccine and Sera: Neutral glass tubing were made in Calcutta and the firms supplied ampoules exactly to the required pattern. Large quantities of ampoules for vaccines and sera were manufactured in Calcutta for the CRI. These withstood the tests for 'limit of alkalinity' laid down in the *BP Appendix No. XVI(c)* and other tests for suitability. By March 1942, ampoules of a total capacity of 5 million cc. were in hand and about 4 million cc. on order. It appeared that indigenous production was adequate for India's requirements. A new type of glass was approved for use as vaccine ampoules and the firm in Calcutta stated that a simpler shape of ampoules would make a 50 per cent. increase in the production possible.

Microscope slides: Slides of different thickness made by a firm in Calcutta were found suitable. Advice was given as to the thickness required for ordinary microscopical work and for dark-ground examinations.

McCartney Bottles: These bottles and their caps and washers were examined. A suitable type of rubber washer was eventually recommended.

Incubator Capsules: These were specially manufactured at Ambala and capsules to work at 37°C. were found satisfactory.

Sterilised Catgut Ligatures: In August 1941, the Director, CRI was asked whether he could undertake the preparation of sterilised catgut ligatures for medical store depots. A supply of unsterilised catgut was obtained from Pioneer Sports Co., Sialkot, and the technique of sterilisation by different methods studied. Eventually the method of heat sterilisation was adopted. The process finally selected was as follows :—

(i) Catgut wound on fibre slips and placed in tubes.

(ii) Dried at 85° C. for one hour and at 105° C. for one hour in the hot air-oven.

(iii) Tube filled with xylene (distilling at 140°C.) and sealed by fusing.

(iv) Tubes heated in oil-bath at 154° C. for two hours.

(v) After cooling the tubes are opened, the xylene drained off and replaced with rectified spirit containing 0·1 per cent. biniodide of mercury and re-sealed.

The first batch was reported on indifferently by surgeons but the second batch was found to be satisfactory.

Production on a small scale (800 tubes monthly of different sizes) from materials which were all indigenous was authorised. The required items were available by the third week of July and the work commenced on 28 July 1941.

The first monthly supply was issued to Medical Stores, Lahore, in September 1941. In each batch 1 per cent. was tested for sterility and tensile strength. The production was continued at the level of 800 tubes a month till March 1942. In April 1942, an approval for increased manufacture at the rate of 10,000 tubes a month was obtained since a demand for 100,000 tubes had been placed for the whole year. By July 1942, production was commenced at the rate of 300 tubes a day and gradually increased to the level of 600 tubes a day in August 1942. Supplies of catgut were ample and a suitable source of supply for glass tubes had been found. A firm in Calcutta promised delivery of 10,000 glass tubes a month but railway delays caused irregularities. Stocks of glass tubes, however, became exhausted in the second half of August 1942, due to interruption in railways and production had to be suspended. Small supplies of glass tubes arrived by passenger trains in October and November 1942, but the normal supply was not resumed till December 1942.

The monthly issues to Government medical stores of sterilised catgut ligatures, manufactured at CRI were as follows :—

TABLE VI

Monthly issues of sterilised catgut ligatures, manufactured at CRI to Government medical stores.

Months		Tubes
August, 1942	...	5,700
September 1942...	...	7,500
October 1942 ...	...	500
November 1942...	...	3,100
December 1942...	...	8,885
January 1943 ...	...	12,207
February 1943 ...	...	8,200
April 1943 ...	...	4,786
May 1943 ...	...	14,723
June 1943 ...	...	19,684
July 1943 ...	...	13,820

The production was held up for a second time for about two months from the latter part of February 1943, as Karnal distillery failed to deliver supplies of rectified spirit. In July 1943, the question of obtaining 000 size ligatures was investigated. But in August 1943, all outstanding orders (130,000 tubes) were cancelled by the Director General of Supply with the result that large stock of raw materials and 13,000 unfinished tubes were on hand.

Agar: A very considerable rise in the price of agar occurred at the outbreak of war and supply was short. A sample of Ceylon moss was examined for its suitability as a substitute for the other seaweeds commonly employed for manufacture of agar (China grass). A satisfactory agar was obtained from the Ceylon moss but in its crude form there was very large insoluble residue when the moss (after soaking in 1 per cent. acetic acid and washing under tap water) was dissolved in nutrient broth in the autoclave. A commercial method for obtaining a preparation free from the insoluble material had to be evolved. In April 1942, a chemist (industrial planning officer), employed under the Director of Production, Drugs and Dressings, was posted to the CRI for this purpose. He tried various methods of extractions and obtained a 30 per cent. yield of agar from Ceylon moss in June 1942. The agar was found suitable and conformed to BP standards.

Travancore seaweeds were also under test. In September 1942, tests were carried out on samples of *gracilaria* from the coast but the yield of agar was lower than that of Ceylon moss and the agar was cloudy and showed a colloidal admixture. The agar was, however, of a very good setting quality and gave adequate growth of all test organisms. The cloudiness in some extracts was reduced by altering the pH of extractions. Further work in October 1942 showed that a very satisfactory preparation could be obtained by freezing strips of the extract and pressing them to get rid of water. This method appeared to have advantages over drying by heat and it was suggested that it should be tried on a large scale in an ice factory in Madras. The industrial planning officer visited Madras in September 1942 to

investigate the question of large scale manufacture of agar from both Ceylon moss and *gracilaria* as large quantities of agar were urgently required for vaccine production. Certain initial difficulties were experienced in preparing the roll-culture bottles with this agar but these were subsequently overcome. The difficulties were mainly due to the relative insolubility of the agar and the tendency of the agar film to crack. In March 1943, the agar manufactured from Ceylon moss at Madras was used for the preparation of cholera vaccine.

Disinfectants : During the war years, the institute took an additional and important function by assuming responsibility for testing of disinfectants offered for Government contracts. Rideal Walker tests were carried out on over 400 samples of disinfectants prepared by commercial firms in India or imported for army use. It was very gratifying to note that a vast majority of products of indigenous manufacture was highly satisfactory, yielding stable emulsions in both ordinary tap water and sea salt mixture.

Inspection Licensing: Another important activity was the inspection and licensing of commercial concerns in India as approved suppliers to Government of biological and other products. A serum standardisation section was established at the institute in 1939, and it continued to function throughout the war. It did valuable work in testing of vaccines, sera, sterile solutions intended for parenteral use, sterile surgical ligatures and numerous other products.

(iii) COUNCIL OF SCIENTIFIC AND INDUSTRIAL RESEARCH

The council carried out various investigations, allied to medical science, during the war including those on vitamin B concentrates, steroids, gland products such as thyroxine, adrenaline, pituitrin, etc., agar-agar and antibiotics.

Disinfectants : P-chloro-m-xylenol was found to be the active constituent of effective disinfectants in common use. This chlorohexanol was prepared from coal-tar acids produced in India, and the whole process of preparing the disinfectant using chloroxylenol soap, essential oils, and alcohol worked out (Board of Scientific and Industrial Research) (BSIR). The process was leased out to a pharmaceutical works in Calcutta for development. The details of the process have since been incorporated in the British Pharmacopoeia.

Preparation of Novocaine: Novocaine was synthesised from easily available raw materials such as toluene, aniline and ethylene. P-nitrobenzoic acid is first obtained from toluene, by nitration to p-nitrotoluene and the subsequent oxidation of the p-nitrotoluene. Diethylamino-ethanol is then prepared by the condensation of ethylene chlorohydrin and diethylamine, which are prepared in turn from ethylene and aniline respectively. Condensation of p-nitrobenzoic acid and diethylamino-ethanol yields novocaine. This was considered as the best scheme for the preparation of novocaine from raw materials available in India.

Preparation of Vitamin B Concentrates: The object of this investigation was to study the conditions for the large scale production of yeast rich in vitamins of the B-Complex with a view to prepare concentrates which may serve as food supplements particularly for the vitamin B factors.

Some twelve different strains of yeast were obtained, the majority of which were isolated in a pure state by the method of dilution and culture from single cells. These were activated and then adopted for growth in three different media, the glucose salt, the molasses salt and the beerwort.

Preliminary studies were made in the vitamin B content of the different strains when grown in the three different media in culture of ½ titre volume. Baker's yeast cultivated on the beerwort medium was found to be the richest source of vitamin B.

Pyrethrum and Pyrethrum Substitutes: Investigations were conducted to evolve a suitable method under existing conditions, for the manufacture of standardised pyrethrum extracts of high concentration and biological stability from pyrethrum flowers, which can be used either in sprays or body creams (BSIR, 1947). As a result of the experiments carried out, an efficient method was evolved for the manufacture of biologically stable extracts of 10 per cent. concentration and upwards. Cheap solvents easily procurable in India and a simple and economic process of cold percolation were used. A sample of the concentrated extract thus prepared was tested by the Malaria Institute of India and the biological evaluation of its toxicity to mosquitoes confirmed that it was a highly effective insecticide.

Mosquito repellent creams with incorporation of the concentrated extract were also prepared (BSIR, 1946).

Emulsifiers for the Preparation of DDT Emulsion Sprays: A number of suitable emulsifying compositions were evolved with the help of Indian turpentine as one of the solvents and easily available emulsifying agents which gave 25-30 per cent. solutions of DDT. The emulsion sprays prepared from these solutions were stable over considerably long periods. Field experiments were subsequently carried out by the Malaria Institute of India.

Synthesis of Phenacetin and Chiniofonum: Work on the synthesis of phenacetin and chiniofonum was carried out with phenol as the starting material. Phenol on nitration gives both ortho and para-nitrophenol. While chiniofonum was obtained from the ortho-compound, successive ethylation, reduction and acetylation of the para-compound gave phenacetin. The conditions of carrying out these reactions to give proper yields of these compounds were systematically studied. In the course of the synthesis of chiniofonum an important antiseptic 'chinosol' was also obtained.

Preparation of 5-chloro 7-iodo-8-oxyquinoline: A method for the preparation of 5-chloro 7-iodo-8-oxyquinoline from phenol was worked out. Phenol was first chlorinated to yield chloro-phenol and the chloro-phenol then nitrated to 4-chloro-2-nitro phenol which was subsequently

converted to 5-chloro-8-oxyquinoline by Skraup's reaction. Iodination of 5-chloro-8-oxyquinoline gave 5-chloro 7-iodo-8-oxyquinoline (BSIR, 1947).

Preparation of Gland Products such as Thyroxine, Adrenaline, Pituitrin, etc. : Under this scheme, the slaughter house of Madras Corporation was thoroughly organised and the various endocrine glands which were practically going to waste were mobilised so as to yield valuable drugs like adrenaline, pituitrin, thyroxine and thyroid extracts.

The large scale production of thyroxine and thyroid extracts was standardised. Thyroxine was isolated in pure crystalline condition and the yields were as good as those reported by Harrington. Incidentally the discovery was made of the usually high organic and thyroxine iodine contents of the glands of local animals (Dey, Krishnan and Girraj, 1945, 1946 ; Ganguly and Dhar Chaudhery, 1946, BSIR, 1945). The production of adrenaline in pure condition from the suprarenal glands of animals was systematically standardised (Dey, Krishnan and Sreenivasan, 1946). The large scale production of the dried posterior pituitary powder from pituitary glands (ox) was also investigated. The final powder on bioassay was shown to be as potent as the international standard (Dey, Krishnan and Girraj, 1944).

The preparation of injectules of both adrenaline and pituitrin was undertaken, and the technique adopted was found satisfactory by the Director of the King Institute, Guindy. An exhaustive study of the conditions for the proper collection and storage of various glands was undertaken. A systematic study of the effect of various antioxidants on the stability of adrenaline ampoules was made. Preliminary investigations on the preparation of insulin from shark pancreas were carried out. Work on the anti anaemic principles of the residue left after the extraction of shark liver oil was started late during the war.

Preparation of Organic arsenical Compounds : Methods for the preparation of several organic arsenical compounds such as the sulpharsphenamine, neoarsphenamine, acetarsone, sodium arsenilate and para-carbaminophenyl arsenic acid were evolved (BSIR, 1943). Fairly large scale experiments on the production of sulpharsphenamine and neoarsphenamine were conducted and good yields of the pure products obtained. Experiments were also conducted for the preparation of the hemi-alcoholate of meta-amino-parahydroxyphenylarsine oxide from 3-amino hydroxyphenol arsenic acid. A method for the preparation of arsenic acid from orpiment and nitric acid was established obtaining 90 per cent. of the theoretical yield.

Production of Atropine, Emetine, Apomorphine, etc. : The production of atropine from belladonna, emetine from ipecacuanha, and of apomorphine from morphine was taken up under this scheme. One important factor which was given great consideration was the question of finding suitable cheap solvents for extracting the active principles. Fusel oil and petroleum ether were successfully used in place of costly and often unprocurable solvents. The processes of extraction were standardised.

Kurchi Alkaloids: Investigations were carried out to gain an insight into the structure of the seven alkaloids earlier isolated from the bark and seed of *Holarrhena antidysenterica* (Kurchi). Exhaustive studies in the action of sulphuric acid (Siddiqui and Vashistha, 1945), permanganate (Siddiqui and Vashistha, 1946) and chromic acid on conessine a compound closely related to these alkaloids were carried out towards this end (Siddiqui and Sharma, 1946).

Manufacture of Agar-Agar: The study of a number of seaweeds was carried out and it was shown that *Gracilaria lichenoides* found along the coast of Travancore is sufficiently rich in agar-agar to form an economical raw material for its large scale production in India. A new and inexpensive method was worked out for the purification of *Gracilaria lichenoides* from Travancore and to obtain bactro-agar of a quality which fully complies with BP and USP specifications (Siddiqui, Bose and Karimullah, 1942).

(iv) HAFFKINE INSTITUTE, BOMBAY

From the time of the outbreak of World War II, the institute had an unprecedented expansion, and work was undertaken to tackle effectively the various problems that arose. The unsettled conditions in the country, the interruptions and stoppage of the regular medical supplies and drugs from abroad and the danger of air raids, called for the manufacture of large quantities of vaccines, different therapeutic sera and other products for the civil and military use. To meet these, the requisite production departments were built up and the existing ones strengthened. There were many unusually high demands and in the course of meeting them the institute also expanded a great deal and today it remains one of the best equipped medical research institutes, both for routine production and research work.

Vaccine Department: To cope up with large demands of the vaccines and also to meet any emergency this department was further strengthened by installing modern equipment and mechanising the production of media. As a result of the research work undertaken, two significant improvements were effected. The new casein hydrolysate medium was developed and it replaced the old mutton digest medium. This new medium gave a very high growth so that the period of incubation was cut down to half. In addition, killing by the use of formalin and adding phenylmercuric nitrate as a preservative gave a vaccine which was free from toxicity. The new plague vaccine proved to be much more potent than the old one.

The cholera vaccine was prepared in the liquid medium. This new vaccine proved to be better than the old agar vaccine and more important, the output could be increased greatly. As a result of these improvements, installation of new equipment and mechanisation of the processes, the capacity of the department rose to about 4 million cc. of the vaccine per month and it could meet any emergency. The quantities of vaccines issued during the years 1940-45 were as follows :—

TABLE VII

The quantities of vaccine issued during the years 1940-45 at the Haffkine Institute, Bombay.

Vaccine	Quantity in cc.					
	1940	1941	1942	1943	1944	1945
Plague vaccine	5,717,127	4,089,888	2,730,798	3,830,643	7,731,383	15,584,809
Anti-cholera vaccine	420,171	2,784,772	3,149,703	3,574,540	4,354,942	6,639,288
TAB vaccine	21,161	67,090	152,331	184,468	232,593	180,119

Of 61,433,000 cc. of vaccines produced in the institute, the approximate quantities that were supplied to the army between 1939-45 were as follows :—

Plague vaccine	...	...	...	2,300,000 cc.
Cholera vaccine	...	...	...	1,625,000 cc.
TAB vaccine	...	...	...	115,000 cc.

Department of Antitoxins and Sera : At the outbreak of World War II, it became impossible to arrange for local production of antitoxins and sera to meet primarily the needs of hospitals. Previously almost all the supplies of antitoxins and sera and toxoids were imported from abroad. The Haffkine Institute, for instance, purchased the antitoxins and sera in bulk from foreign exporters and bottled them in ampoules for use in the hospitals of the city of Bombay and the province in general. These imports stood the risk of being cut off entirely, and the supply position became uncertain. Thus, pressed by the essential needs of the province of Bombay in particular, and of the country in general, the Government of Bombay approved of establishment of the new department of antitoxins and sera at the Haffkine Institute.

This new department commenced large scale production of antitoxins, sera and toxoids. Difficulties of getting plants, machinery and laboratory wares during war time were overcome. It was very soon realised that the potential demands of the country, for use of these antitoxins, sera and toxoids amongst the civil population alone, were very high. The needs of the army during the war would naturally be enormous. As the CRI Kasauli, was looking after the entire needs of the army, the Haffkine Institute primarily met the needs of the civil population, as far as it was possible within the limited scale of production. During the war years between 1941 and 1946, 3,306,323 cc. of finished products, such as concentrated and purified antitoxins, sera

and toxoid were issued for use. The detailed list of supply of different items is given in Table VIII.

TABLE VIII

Supply of antitoxins, sera and toxoids during the war years—1941-46.

Description of item	Quantities in	
	Number of ampoules	cc.
(i) *Tetanus Antitoxin*		
(a) Prophylactic—3,000 IU in 2 cc. ...	5,06,695	10,13,390
(b) Curative—20,000 IU in 10 cc. ...	51,394	5,13,940
(c) Curative—10,000 IU in 5 cc.	796	3,980
(d) Highly concentrated—20,000 IU in 4 cc. ...	26,550	1,06,200
(e) Diluted—1,000 IU per cc. (bulk supply) ...	...	2,03,000
(ii) *Diphtheria Antitoxin*		
(a) Prophylactic—1,000 IU in 2 cc. ...	17,443	34,886
(b) Curative—10,000 IU in 10 cc. ...	30,582	3,05,820
(c) Curative—5,000 IU in 5 cc.	589	2,945
(d) Highly concentrated—10,000 IU in 5 cc. ...	20,383	1,01,915
(iii) *Gas-gangrene Antitoxin*		
(a) Welchii antitoxin—3,000 IU in 10 cc. ...	25,410	2,54,100
(b) Polyvalent prophylactic, Welchii 3,000 IU Septique, 1,500 IU and Oedenatins, 3,000 IU in 10 cc.	253	2,530
(c) Highly concentrated polyvalent prophylactic, Welchii 3,000 IU Septique, 1,500 IU and Oedenatins, 3,000 IU in 4 cc.	3,218	12,872
(d) Polyvalent therapeutic, Welchii 9,000 IU Septique, 3,000 IU and Oedenatins, 9,000 IU in 15 cc.	2,675	40,125
(iv) Antiplague serum in 20 cc. ...	10,766	2,15,320
(v) Lyophilised polyvalent anti-snake-venom serum in 10 cc.	8,957	89,570
(vi) *Antidysentery Serum (Shiga)*		
(a) Natural, 4,000 IU in 20 cc.	14,568	2,91,360
(b) Concentrated, 4,000 IU in 5 cc. ...	1,878	9,390
(vii) *Tetanus Toxoid*		
(a) in 10 cc.	5,974	59,740
(b) in 5 cc.	1,515	7,575
(c) in 1 cc.	5,340	5,340

Particular efforts were made to improve the production of the anti-snake-venom serum, for which the country was entirely dependent upon its own produce. The bivalent liquid serum which was the only serum available till the Haffkine Institute antivenene was issued, was effective only against the venoms of the cobra and the Russell's viper. The victims of bites of the Krait and the Saw-scaled viper, the two

other common poisonous snakes of India were not protected by the bivalent serum. Hence, a polyvalent serum, effective against the venoms of all the four common poisonous snakes of India, was prepared and issued in the lyophilised form. The two-fold advantage of lyophilisation was (i) that the serum maintained its potency over ten years even if stored under common storage conditions, and (ii) that being a dry powder, the serum could be carried in any container anywhere without involving spilling after accidental breakage of the ampoule. This polyvalent antivenene was used both by the military and the civil population.

Department of Chemotherapy : This department was organised and fitted up during the war period. As a result of the researches in the sulphonamides, sulphathiazole was found to have a curative action in bubonic plague ; the entire quantity of the drug used for the clinical trial was prepared by the department. The method of preparation of this drug on a large scale was worked out and a modern pilot plant was fitted up and production started on a semi-commercial scale. The drug prepared was supplied to the Government hospitals. Work on the manufacture of the synthetic and antimalarials was also carried out. Due to the shortage of antiseptic solutions for external use, a new preparation called Pemon was developed and this was used in the Government hospitals and dispensaries. The department also prepared and supplied phenylmercuric nitrate, the antiseptic used as a preservative in the vaccines manufactured in the institute.

Department of Pharmacology: This department directly contributed to the cause of war in many ways. The samples sent by the military authorities were tested for their specifications. For this purpose a unit was maintained and it tested during 1942-46, 6,568 samples which were sent by the officer commanding, medical stores inspection depot. They consisted chiefly items of apparatus, surgical dressings, glassware for alkalinity tests, injectible preparations for sterility tests, mosquitocidal sprays, etc.

The problem of prevention of infection of war wounds was investigated experimentally at the request of the army authorities which resulted in the elaboration of a technique which was extensively tried in the field with good results. The technique consisted in applying to the wounds, a specially made cod liver oil sulphonamide paste through a rubber nozzle attached to a collapsible tube and dressing the wound with a sulphanilamide impregnated cotton wool pad borne on an elastoplast. About 15,000 such tubes and nearly 8,000 special occlusive dressings were prepared and sent to the army for a large scale experiment. The paste was also used by Government civil hospitals.

There was a large demand for the glucose saline for the army and air raid precaution organisations, and so large scale preparation of these were undertaken. About 3,500 litre of glucose saline was supplied to various organisations. In addition morphine solutions and mydiacin solution (6,692 ampoules) were also prepared and supplied.

In addition, military medical authorities referred some of their problems to the department for investigation. Examinations like testing

the suitability of certain special anaesthetics or determination of the toxicity of some organic arsenicals whose purity was doubted, were undertaken. A new anaesthetic ' trichloroethylene ' was fully investigated with a view to find its suitability as a general anaesthetic.

(v) INDIAN INSTITUTE OF SCIENCE, BANGALORE

The biochemists of the Indian Institute of Science in Bangalore were actively engaged during the war in various problems relating to the preparation of rennet, vitamins, etc.

Rennet : To meet the requirements of the defence services sufficient rennet was made to produce three to four tons of cheese per day. Large quantities of junket rennet were also prepared. Vegetable rennet was made out of the latex of *ficus carica* by freezing out the latex filtrate and quickly evaporating it in vacuum, or alternatively by acetone precipitation. It was found that while the vegetable rennet is universal in action, animal rennet has no coagulating action on soya milk. In collaboration with Indian Dairy Research Institute, trial tests for making cheese using this enzyme preparation were carried out satisfactorily. On the request of the Supply Department of the Government of India, manufacture of rennet tablets (about 50 lbs. per month) was started and tested with encouraging results (Bhima Rao, Lakshmi Narayana Rao, Jagannathan, Ramaswamy, Krishna Murthy and Subrahmanyan, 1941-43, 1946, 1947).

Vitamin B: Methods were worked out for quantitative extraction of vitamin B_1 from rice bran, using N/10 acid, absorption on active charcoal and elution under suitable conditions (Rao, Suryanarayana Murthy, Madhava Rao, Ramachandran and Sivaramakrishnan, 1941-43) and for production of vitamin B complex from yeast, by utilising the by-products of the preparation of calciferol (Sreenivasaya, Sarma and Ramaswamy, 1942). The former method gave a good yield of a highly potent concentrate of vitamin B_1 suitable for many pharmaceutical purposes. Groundnut was found to be a rich source of vitamin B_1 and unlike yeast all the vitamin content in the nut is in an available form. A process was developed for further enriching groundnut with vitamin B_1. The enriched groundnut constituted a convenient and cheap way of supplementing food with vitamin B_1 (Giri, 1947).

Vitamin D : Manufacture of vitamin D was undertaken by the institute and about 3,600 lbs. of liquor calciferlis was made and supplied to the Defence Department. The liquor calciferlis was prepared in the form of calciferol (vitamin D_2) starting from yeast via ergosterol and irradiation (Sreenivasaya and Ramaswamy, 1941-43).

(vi) KING INSTITUTE OF PREVENTIVE MEDICINE, GUINDY, MADRAS

Of the numerous activities conducted in various sections at the King Institute of Preventive Medicine, two were initiated on account of the conditions created by the war, viz., the blood bank and the department of antitoxins. The blood bank was started early in 1941, primarily

meant for air raid victims. Very occasionally, however, supplies of whole blood and plasma were made to the local military hospitals. The department of antitoxins was started to meet the shortage in the supplies of therapeutic sera which were till then being imported from abroad.

The institute's direct war effort was, however, much limited in scope. So far as the biologicals were concerned, they were being obtained by the military authorities, stationed in the south, from the CRI Kasauli. The King Institute had to make emergency supplies only, particularly cholera vaccine, in certain circumstances, i.e., when for one reason or another such supplies were not received by them in time from the CRI, Kasauli. Vaccine lymph, however, was being regularly supplied by the institute to the Indo-Burma theatre.

The public health section of the institute was called upon to undertake various types of work on behalf of the military authorities during these years. The facilities available at the institute were fully utilised and help and advice on many subjects were given to the armed forces stationed in different parts of the province. To cope with the heavy demands made on the time and resources of this section, the staff was also augmented.

While the samples of water from military sources were usually examined at the brigade laboratories, the advantages of getting expeditious reports from a well established and equipped laboratory situated at a central place were soon recognised by the military medical authorities. A special sample taker was also appointed to help in the proper collection and transport of water samples from different military camps to overcome sampling errors and to gather all relevant information regarding the source, etc., from which the samples were drawn. A close liaison was thus established between the military authorities in charge of camp water supplies and the institute. In all cases, samples of water received from the military sources received high priority and the analytical reports and necessary advice were sent to the authorities expeditiously.

(vii) PASTEUR INSTITUTE AND MEDICAL RESEARCH INSTITUTE, SHILLONG

LABORATORY FACILITIES RENDERED TO THE ARMY

The following arrangements were made between the Central and Assam Governments for carrying out laboratory examinations at the Pasteur Institute, for all entitled military patients from Happy Valley and Shillong, for the duration of the war. A wholetime trained military sub-assistant surgeon and an IHC laboratory attendant, to do the actual work at the Pasteur Institute, were to be provided by the military authorities and they were to have full use of all facilities available at the institute ; in return, the Government of Assam was to

receive annually from the Defence Service Estimates, a lump sum, subject to revision. With the arrival, in May 1941, of the trained officer and the attendant, the military section at the institute started work.

There was a steady increase in the number of samples handled by the military section from month to month, with the result that towards the end of 1942, the DADP held consultations with the director of the institute with a view to expanding the military section into a district or base laboratory to serve the whole Assam area. Under this arrangement the military were to provide special glassware and biological reagents ; the rest of the equipment, such as sterilisers, incubators, balances, microscopes, microtomes, ordinary glassware, animals, supply of gas and expendible stores, etc., being provided by the institute. For the increased facilities provided, the Assam Government was to receive a bigger lump sum grant from the army. The district laboratory commenced to function in January 1943. To begin with, its staff consisted of the officer-in-charge, a recognised specialist in pathology, an assistant surgeon, one RAMC laboratory attendant, three other laboratory attendants, two sweepers and a clerical havildar.

The district laboratory continued to work at the institute for the duration of the war and for sometime thereafter and finally shifted to the CMH at Shillong on 8 April 1946.

SUPPLY OF ANTIRABIC VACCINE

According to rules framed by the Assam Government antirabic vaccines for human beings could be supplied by this institute only to recognised antirabic treatment centres. About 76 centres were distributed over the province, and patients at risk were required to apply for their treatment to the nearest recognised treatment centre. In August 1942, the DMS in India represented that during the then existing emergency, dangerous delays were likely to occur, because of poor communications, if military cases had to be transferred to the existing antirabic treatment centres. It was, therefore, decided that treatment should be given in any army medical unit at the discretion of the DDMS, Eastern Army. The army obtained antirabic vaccine from the Pasteur Institute, Shillong, in the case of the Assam area and certain adjoining areas of Eastern Bengal and maintained a minimum stock of the vaccine in the larger medical units, e.g., general hospitals and CCSs, for immediate issue on demand to dependent smaller medical units. At a later date, it was decided that all hospitals and CCSs were to hold vaccines for two courses and one course, respectively ; in addition, an emergency reserve of five courses were to be held at all base and depot medical stores.

The number of courses of antirabic vaccine supplied to the army under the above arrangement was 96, 454, 562 and 99 for the years 1943, 1944, 1945 and 1946 respectively. The demands ceased in 1947. These courses do not include those given to military patients from Shillong, Happy Valley and the neighbouring military camps, who applied for treatment at the Shillong centre located at the Pasteur Institute and also at some of the mofussil treatment centres.

ANTIMALARIAL SURVEYS IN CIVILIAN AREAS IN THE VICINITY OF AERODROMES AND AIR FORCE STATIONS

The Government of India, in November 1942, desired that the civil authorities should put into force suitable antimalarial and sanitary measures in the immediate vicinity of aerodromes in Assam, with a view to reducing the risk of infection in air force camps and personnel. At the request of the Assam Government, the Assam Medical Research Society undertook the malaria control work and submitted a scheme which was approved by the Inspector General of Civil Hospitals, Assam. There were 12 aerodromes in the province, but this number rapidly rose to 20 within a short period. According to the scheme, two survey units, each consisting of a medical assistant and a malaria inspector from the society, were to carry out a rapid malaria survey of the areas concerned, their work being supervised by the malariologist of the society. Their pay was to be met by the society, but owing to the hazardous nature of the work, they were to receive extra remuneration which was to be borne by Government together with their travelling and halting allowance. The civil surgeons were responsible for carrying out the recommendations of the survey units. A malaria inspector with labourers at his disposal carried out the measures at and around each of the aerodromes. The work of the several inspectors was checked by a malaria trained sub-assistant surgeon. The malariologist of the society inspected the actual working of the measures by occasional visits and rendered technical guidance.

Work started in December 1942 and by May 1943, surveys had been carried out in respect of all the 20 aerodromes, with the exception of one, where the society was not required to carry out the survey.

In December 1943, the American Army authorities took over the malaria control of the environs of aerodromes, and the responsibility of the society in regard to it ceased thereafter.

Earlier, in 1942, the services of three members of the Assam Medical Research Society—the malariologist, a malaria inspector and an office assistant—were placed at the disposal of the military authorities for a period of about six months.

ASSAM BLOOD BANK

As part of the general scheme of the DGIMS to have a civilian blood bank in each of the provinces in India, to produce and stock sufficient serum or plasma for victims of possible air raids, the Assam Blood Bank was organised in April 1942, and started working at the Pasteur Institute towards the end of August 1942. By the end of the year, 50,525 cc. of serum had been stocked. During the following year, 83,500 cc. of serum was issued, including 40,500 cc. stocked at six mofussil centres considered most vulnerable to attacks from the air. The blood bank at Shillong was left with a balance of 84,500 cc. of serum at the end of 1942. In order to reach the remote parts of the province for

collecting blood from donors and processing it into plasma at the institute, sanction was obtained for a motor van with a refrigerator. It commenced touring the province during the following year. In 1944, there was a switch over from serum to plasma and the quantities issued during the year amounted to 80,500 cc. of serum and 8,500 cc. of plasma. The blood bank was closed under orders of the Government on 30 September 1945. On this date the quantity of plasma or serum held at Shillong was 81,150 cc. and at 14 mofussil centres 95,300 cc.

EVACUATION FROM BURMA

With the occupation of Burma by the Japanese in 1942, evacuees from Burma began to stream into Assam by the overland routes. To protect them and the labour force engaged in numerous army projects from cholera, abnormal demands were made during 1942 on the institute for the supply of cholera vaccine. From the average annual issue of cholera vaccine during the quinquennium preceding the war, amounting to 500,000 cc., the demand for this vaccine rose in 1942 to two million doses with a proportionate increase in demands for TAB and combined cholera and bacteriophage. Consequently, the staff had to be strengthened by employing temporary hands, and the work of the vaccine section had to be carried out in double shifts for varying periods during 1942 and 1943. During the remaining years of the war the demands were less and remained at a steady level.

(viii) SCHOOL OF TROPICAL MEDICINE, CALCUTTA

During World War II, the teaching work of the school was extended to cover organised short courses of instruction in tropical medicine, protozoology, helminthology, bacteriology, haematology and clinical pathology for the army medical officers, British and American.[3] In addition numerous officers attended the school singly or in groups to gain experience in tropical disorders. On many occasions the different departments of the institute were called upon for information and advice regarding tropical diseases, e.g., malaria, dysentery, kala-azar, anaemia, filariasis, rat-bite fever, leprosy, etc., occurring in army personnel. The staff of the school were also asked to visit military hospitals and advise regarding diagnosis and treatment of patients. Sera of suspected cases of Weil's disease were sent by military hospitals in different places for diagnostic tests.[4] A special study on the incidence of amoebiasis amongst military personnel was undertaken at the instance of the American Medical Directorate, Calcutta. Stools of over 750 persons were examined, and about 30 per cent. were found positive on single examination only. Members of the staff attended the clinical meetings held in local army hospitals, demonstrated cases from the school and took part in the discussions.

[3] Number of military officers attending the courses held at the school from 1942-1945 was: IMS/IAMC 9 RAMC 68 USA 61 RAF 15 Total 153.

[4] Number of sera examined for Weil's disease referred to by the military hospitals from 1942 to 1945 was 150.

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CHAPTER XL

Biochemical Research

During World War II, the AHQ started a few research units to carry out investigations on subjects which had a direct bearing on wastage of manpower. Research work was also carried out by individuals and organisations, both official and unofficial, which affected the practice of clinical biochemistry in the armed forces. Technical methods designed outside India were also tried in the army to evaluate their usefulness and limitations and many modifications were evolved. A survey of the contributions towards the advancement of medical science during the war reveals that in many fields, biochemistry offered a number of solutions to difficult problems. The war in its turn vitalised the biochemical research in India, and its effects are reflected in the increased work in biochemistry in the post-war period. An attempt has been made in the following pages to review some of the work done in the army and outside which directly or indirectly affected the armed forces.

BIOCHEMICAL RESEARCH CARRIED OUT BY THE ARMED FORCES IN INDIA

Sprue: Extensive biochemical studies made in case of sprue[1] have been discussed in the chapter dealing with this disease.

Anaemia[2]*:* In 1944, the Anaemia Investigation Team (Medical Research Organisation) of GHQ found that there was a widespread mild, and sometimes severe chronic microcytic anaemia in recruits and troops in North-West India, which readily yielded to massive iron given in the form of ferrous sulphate. It was, therefore, thought necessary to find out whether the troops had originally been living on an iron-deficient diet or whether iron absorption was in any way impaired. With this aim in view, a biochemical laboratory suitable to perform food analysis and other biochemical investigations likely to be needed, was attached to the team.

The task before the biochemist was to see first whether the food given to the anaemic soldiers contained enough iron. In view of the fact that there might have been some defect in the iron absorption, the following investigations were carried out :—

- (i) determination of available iron in fresh food and in cooked food digested with stomach juice (pepsin).
- (ii) investigation of the gastro-intestinal function of the troops.
- (iii) determination of serum iron before and after the intake of iron alone, and iron together with the food generally consumed by the troops.

[1] See also page 418.

[2] See Chapter II. For a detailed report of the work of the team, see *Report on investigation on Anaemia in the Indian Soldiers* (1945-46), published by the GHQ Medical Research Organisation. See also volume on *Prevention of Diseases, Malaria Control and Nutrition.*

The last subject, however, could not be investigated as the team ceased to function before this investigation could be completed.

During iron analysis of various items of food it was seen that the iron content of the diet usually consumed was fully adequate, but only one-third of the Indian soldiers serving in Peshawar district had over 14 g. per cent. of haemoglobin, and in Rawalpindi, about 50 per cent. had over 14 g. There was a very rapid rise in haemoglobin in men having lower haemoglobin values, when iron was administered in the form of ferrous sulphate. It was concluded that the total iron available in the Indian Army rations was far higher than the minimum iron necessary for nutrition, and it became necessary to focus the attention on the study of the availability of the food-iron. From the existing literature it was quite evident that the availability of iron *in vivo* did not depend on the chemical availability, and therefore, experiments were arranged to imitate conditions as might be present in the stomach. The foodstuffs were incubated with hydrochloric acid and pepsin and the amount of iron which became soluble was estimated. Experiments were also carried out to investigate the effect of vitamin C on the solubility of iron in these digests. It was shown that the availability of the iron was much less than the total iron available, and that it varied greatly with presence of hydrochloric acid, pepsin and vitamin C. The experiments thus suggested that with deficient gastric activity, the iron intake amongst Indian troops might be lower than could be assumed from the iron content of the food.

It was also necessary to find out whether the food was really generally consumed to the extent in which it was set out in the ration tables. On detailed investigation it was discovered that the food intake was definitely lower than that prescribed by the official ration, which might have been the cause of iron deficiency found amongst the soldiers. It was proved that though the daily ration of *atta* was 24 ozs., and of *dal* $4\frac{1}{2}$ ozs., the actual intakes after cooking were only 13 ozs., and $3\frac{1}{3}$ ozs., respectively. The influence of sieving, which was a widespread practice, on the constitution of *atta* was examined, and it was found that sieving leads to a loss of iron. The loss was, however, entirely in the hard core non-available fraction, there being no real loss of the easily available iron. Sieving was, therefore, not considered to be a dangerous practice. It was also shown that soldiers suffering from a simple iron deficiency anaemia showed a slow but gradual rise of haemoglobin when they were put on a specially supervised diet with optimal amount of *atta* and *dal*.

Another line of investigation that was taken was to find out whether the production of hydrochloric acid and pepsin in the stomach of normal and anaemic Indian soldiers was satisfactory. In all the cases full haematological picture was evaluated and fractional test meal analysis was performed using oatmeal gruel. The gastric contents were examined for free and total acidity and pepsin was measured by the digestion of edestin by stomach juices in different dilutions. From this study it was concluded that defective gastric function, while rarely found in post-malarial anaemia, was common in anaemia following

dysentery or due to worm infection, and that cases of anaemia after dysentery seemed particularly prone to show deficient stomach function.

During the investigation of gastric function, it was noticed that the pepsin production was frequently deficient in the post-dysenteric state, regardless of whether the patients were a-, hypo- or normo-chlorhydric. In 50 per cent. of such cases little or no pepsin rise was seen after a gruel test meal, but it was commonly seen that histamine injection led to the production of pepsin even in achlorhydric patients.

The serum proteins of anaemia patients were estimated and it was found that except in a very few cases where the value of total protein was below 5·6 per cent., all others had values within normal limits. It was, therefore, concluded that serum protein estimation is a less sensitive test for malnutrition than haemoglobin estimation.

In the course of serum protein estimations, the specific gravity method as devised by Phillips, Van Slyke, Dole, Emerson, Hamilton and Archibald (1945) was compared with other methods, e.g., Kjeldahl and nesslerisation, and it was found that the specific gravity method was sufficiently accurate to be usefully employed in clinical medicine. The apparent inaccuracy of plasma protein estimation by this method was checked up in various ways but no explanation could be put forward. The reliability of the specific gravity method in the calculation of haemoglobin was thoroughly checked. It was found that although the method is less accurate than the Sahli's haemoglobinometer technique, it has the advantage of great rapidity ; for to pick out the anaemic members of a group it is only necessary to put one drop of blood from each person into copper sulphate solution corresponding to the haemoglobin value chosen as the limit. If the drop floats, the individual is taken as anaemic.

The reliability of determination of packed cell volumes by specific gravity method, under conditions found in India, was also investigated. This investigation was specially necessary owing to the fact that high speed centrifuges or even electrical energy are not available everywhere. It was observed that value of packed cell volumes calculated from specific gravities of whole blood and plasma were about 10 per cent. lower than those measured directly by centrifuging. The difference was greater in anaemic blood.

Intensive study of the specific gravity methods was made from all its aspects and simplified modifications on the technique were also suggested. It was noticed that extreme accuracy of the specific gravity of the stock solution was essential, because a difference of 0·001 in the specific gravity of the solution is equivalent to 0·343 g. of protein per 100 cc. Fairly accurate stock solution could be prepared by the simpler method of dissolving 159·62 g. of pure crystals of copper sulphate (AR brand) in distilled water and making the volume to one litre at room temperature. It was necessary to check the specific gravity by gravimetric method. To simplify the method further specially in the field where accurate weighing was not practicable, it was suggested to supply the field laboratories with sealed tubes containing the requisite amount of copper sulphate prepared by the base laboratories. The

solution of required specific gravity is to be made by simply dissolving the content of the requisite tube in 100 cc. of distilled water. From the above study it has been concluded that the specific gravity method is sufficiently accurate in giving data readily about the concentration of plasma protein and concentration of haemoglobin. The method could not be employed in differential estimation of proteins, so commonly required, and therefore, the use of the method in general clinical pathology is limited.

A simplified test for deciding whether plasma or saline is to be used for intravenous infusion during resuscitation in the field was also devised. The test involves the use of two small bottles of copper sulphate solution of different specific gravity.

Marasmus[3] : With a view to studying as fully as possible the marasmic conditions amongst the Indian soldiers who were prisoners of war in the eastern theatre and were being repatriated after cessation of hostilities, the marasmus research team was formed in 1945, as a part of the GHQ medical research organisation. Some 2,000 patients were examined, all POW, from different places of eastern theatre. In addition to clinical study, a thorough haematological and biochemical study was made in great detail in certain number of selected cases.

It was observed that most of the POW had a low serum protein concentration, the average being 5·40 g. per 100 cc. The mean serum albumin was 2·63 g. per 100 cc. and serum globulin 2·77 g. per 100 cc. Thus the reduction in the serum protein was entirely in the albumin fraction as also shown by a low albumin/globulin ratio. There was a fairly good correlation between the serum protein concentration and development of oedema. The relation was more close with the serum albumin than with total protein. It was noticed that widespread oedema with ascites developed when the serum albumin fell below 2 g. per 100 cc. and gross generalised oedema with marked ascites developed when it fell below 1 g. per 100 cc. There was, however, no significant correlation between the haemoglobin concentration and the serum protein concentration. On the average, the haemoglobin concentration was more reduced than the serum protein.

A very striking feature was the low serum calcium values (mean 8·5 mg. per 100 cc.) observed in most of the patients. In none of the cases there was any clinical sign of calcium deficiency. Even in cases where serum calcium was as low as 5 mgm./100 cc. there was no evidence of tetany.

There was no significant change in the serum inorganic phosphorus or serum phosphatase. These findings are in favour of the view that the low serum calcium is not related to vitamin D deficiency. Serum urea, plasma prothrombin, plasma fibrinogen, vitamin C saturation test and plasma bisulphite binding power were also determined, but in all cases the figures were well within the normal range.

[3] For a detailed report on this study, see the '*Report on investigation on the Marasmus Syndrome in the Indian Soldiers* published by the GHQ Medical Research Organisation (1945-46). See also page 275.

All the biochemical abnormalities noted improved rapidly with treatment in the hospital. It was also noticed that when a plasma protein infusion was given to a patient with severe hypoproteinaemia, only a small portion of the infused protein was found in the circulation 24 hours later. The percentage of infused protein retained was related to the mean serum protein concentration and to the total circulating plasma protein. When, however, a blood transfusion was given to a patient suffering from extreme macrocytic anaemia with apparently only slight evidence of protein deficiency, the haemoglobin of the blood remained in the circulation, but the plasma protein was no longer present 24 hours later and, in some cases, some of the plasma protein that was originally present in the circulation had also left it. On the other hand, when a blood transfusion was given to an anaemic patient who was neither macrocytic nor hypoproteinaemic, both the haemoglobin and the plasma protein of the infused blood were retained in the circulation 24 hours later.

Fractional test meal analysis was done on a series of 21 patients with oatmeal gruel as the test meal, and after giving 1 mg. histamine subcutaneously to achlorhydric cases. It was observed that two cases had histamine resistant achlorhydria, five had no free acid after the meal but responded to histamine, one had hypochlorhydria, three had delayed emptying time and ten were normal. After treatment in the hospital, all produced free acid even without histamine. Nicotinic acid had no effect but there was a marked improvement in the fractional test meal analysis findings while the patients were receiving riboflavin or liver extract. This showed that both liver extract (which contains riboflavin) and riboflavin alone have beneficial effect on gastric function.

It has generally been believed that starvation is invariably accompanied by a failure of absorption from the gastro-intestinal tract, but diarrhoea and other signs of impaired absorption were surprisingly rare amongst the Indian prisoners. Only in a very few cases, slight evidence of absorptive defect was present. The patients having diarrhoea had steatorrhoea as well, and all had clinical evidence of nicotinic acid deficiency.

Glucose tolerance tests showed some impairment in these cases, which was characterised by (a) a low fasting blood sugar, (b) a low rise in blood sugar after ingestion of 50 g. of glucose, and (c) the curve taking longer time to return to the fasting value. This impairment was considered to be due to a defective absorption from the gastro-intestinal tract. It was also observed that riboflavin had no effect whatsoever on the glucose tolerance, but there was definite improvement when the patients were receiving nicotinic acid, alone or with liver extract.

Fat tolerance tests were done on those patients who had an impaired glucose tolerance. The patients after 12 hours fasting were given a standard fat meal consisting of one tin of twice concentrated unsweetened milk (equivalent to 22 g. of fat). The serum total fat and serum cholesterol were determined at the end of two, three and

four hours. In normal controls, there was a rise in the total serum fat and in serum cholesterol, two to three hours after the fat meal. In the recovered POW the absorptive curve was flatter, and the time taken for the maximum concentration to reach was longer. Fasting serum cholesterol was considerably reduced, but the fasting serum total fat was within normal limits. It was also noted that there was no change in the fasting serum total fat but there was a marked increase in the fasting serum cholesterol. The rise in serum total fat after the standard fat meal also increased but there was no effect on the rise in cholesterol. There was thus definite improvement in the fat tolerance. It was also observed that there was a good agreement between the different tests of absorptive function both of carbohydrate and of fat.

During the course of the fat tolerance test, the serum inorganic phosphorus was estimated in some cases. It was found that after the fatty meal, the serum inorganic phosphorus nearly always increased. Neither the height nor the time of the rise, observed in the prisoners with impaired fat absorption, was significantly different from that of a control group whose fat absorption was normal. It was thought unlikely that the rise in the serum inorganic phosphorus is due to absorption of large quantities of inorganic phosphorus from the gastro-intestinal tract, but it was presumably due to the fat in the milk meal and not to its carbohydrate or phosphate content.

Faecal fats of the patients showing absorptive defects were also estimated. Most patients with diarrhoea also had steatorrhoea which, however, improved during treatment in the hospital.

Toxicity of Mepacrine : During the war in South East Asia, it became necessary to put the troops on suppressive treatment of malaria by means of mepacrine for considerable periods. Minor disorders were noticed in a few cases under this treatment. To investigate the toxicity of mepacrine, a research team was formed by GHQ, which functioned from December 1944 to May 1945, and studied about 80 selected cases, having suppressive treatment with mepacrine, in the Arakan front. The investigation consisted of the study of haematological, renal and hepatic systems. The minimum period, for which mepacrine had been taken, was five weeks and the maximum was 30 months. The men selected had no history of malaria, syphilis, jaundice, amoebic dysentery or any chronic bowel infection during the preceding twelve months.

A detailed haematological study, including RBC and WBC and reticulocyte counts and haemoglobin estimation, revealed that these were all within normal limits.

It was observed that urea clearance amongst the Indians and Anglo-Indians was rather low judged by English and American standards, but the results in the mepacrine series could not be considered abnormal on account of the fact that the average result of urea clearance amongst healthy young Indians has been reported to be quite low by Gokhale (1941).

The plasma phosphatase activity was within normal limits, and so also was hippuric acid excretion. Serum bilirubin, plasma albumin and urobilinogen were all found to be normal. In a few cases, however, the plasma globulin was found to be raised. These cases were studied in more detail and flocculation tests, e.g., colloidal gold, Takata-Ara, gum mastic flocculation and alcohol flocculation tests were performed. Definitely abnormal results were obtained in few cases, but it was noticed that the abnormal results obtained had no relation with the length of time for which mepacrine was taken. Further study revealed that the cases showing evidence of globulin abnormality had history of having suffered from some other diseases in the past, e.g., infective hepatitis, nephritis, amoebic dysentery and malaria or malaria-like fevers, which by themselves might be the cause of hyperglobulinemia.

From the above study, it was concluded that there was no evidence of adverse effects of having mepacrine regularly as in suppressive treatment. In a few cases where abnormal plasma proteins were detected, the cause was attributed not to mepacrine, but to other factors including improperly suppressed malaria.[4]

BIOCHEMICAL RESEARCH DONE OUTSIDE BUT HAVING EFFECT ON THE ARMED FORCES IN INDIA[5]

VITAMINS

Vitamin A : Due to acute shortage of cod liver oil during the war biochemists began to look to the fishes in the numerous rivers, canals and tanks of India for any source of vitamin A. Seshan (1940) found that liver of many fresh water fishes, e.g., *Arh, Boal, Shole, Dhain, Shillang,* etc., were exceedingly rich in vitamin A, viz., to the extent of 20,000-45,000 IU per g. The shark liver oil was found to contain 8,000-24,000 IU per g. No vitamin A was, however, detected in the body fats of these fishes. Basu, Rai Sircar and Sen Gupta (1940) also estimated the vitamin A content in the liver oil of some of the above fishes but found values much lower than those found by Seshan (1940). Nevertheless, these experiments indicated that these fishes so common in India, were very rich sources of vitamin A. Of all the fish oils, shark liver oil was considered to be a good source for development on a large scale. The manufacture of the oil was undertaken in several provinces and approximately 1,400 gallons of the oil was produced in 1940. The vitamin A content of this oil was found variably by different workers. Since the taste and odour of the shark liver oil was very disagreeable and it contained very large amount of vitamin A, Basu (1941) and Basu and Sen Gupta (1941) considered the possibility of using vegetable oil enriched in vitamin A by the addition of concentrates of the vitamin. Such oils have largely been recommended on the grounds of palatability and availability of the vitamins. Shark liver oil diluted with pure arachis oil so as to have 1,000 IU of

[4] See also page 269.

[5] For the work done in the Central Research Institute, Kasauli, Indian Institute of Science, Bangalore, and Council of Scientific and Industrial Research, see chappter XXXIX.

vitamin A per g. was suggested as a replacement to oleum vitaminatum (BP). It has, however, been pointed out that though this preparation could replace cod liver oil as far as vitamin A was concerned, it did not contain any vitamin D which is also present in the cod liver oil. Rajagopal (1942) found a special variety of shark liver oil which contained 190,000 IU of vitamin A in a gram. He suggested that this oil could be substituted for proprietary vitamin A concentrates. Studies on vitamin A continued in later years of the war and the industry of shark liver oil progressed steadily. In 1944, about 10,000 gallons of the oil was manufactured mostly in Madras, Travancore and Bombay. With the development of the industry, the question of the stability of the vitamin in the shark liver oil arose. Rao (1945a) observed that the vitamin is destroyed by the peroxide which is gradually formed in the oil. Rao (1945b) also found that metals like copper, steel, nickel, aluminium, tin and zinc catalyse the oxidative destruction of the vitamin, in the order given. It was, therefore, suggested that zinc is to be used for processing and storage of shark liver oil, it having the least catalytic effect. Bose and Banerjee (1945) observed that destruction of vitamin A proceeded as rancidity developed. They studied the action of different substances in protecting the vitamin and found that a mixture of isobutyl gallate and citric or tartaric acid was best of all. Karmakar (1944) found that vitamin A is almost completely destroyed at high temperatures such as are involved in frying.

While studying vitamin A content of liver oils, viz., *mushi* (*Scoliodon sorrokowah*), *wagli* (*Dasybatus imbricatus*), *shengti* (*Macrones gluilo*) and *ghol* (*Scioena miles*), Niyogi, Patwardhan and Acharya (1943a) observed seasonal variation in the yield of the oil. In case of *shengti* and *ghol* the vitamin A concentration was found to increase as the yield of the oil decreased.

Studies were also made on the carotene contents of dehydrated vegetables which formed part of the army rations. Sekhon (1943) found that vegetables like bitter gourd, cabbage, cauliflower, carrots, pumpkin and potato showed a progressive loss in the vitamin content after dehydration. He found that greater the percentage of chlorophyll content in the vegetables, more pronounced is the destruction of carotene in the presence of light. This observation has a great bearing on the industry of dehydrated vegetables.

Some studies were also made on the relation of vitamin A deficiency to degeneration of the nervous system. Verma (1942) described some cases of partial degeneration of optic nerve associated with vitamin A deficiency. Mild cases of this disease responded well to shark liver oil.

Vitamin D : In spite of wide prevalence of rickets and osteomalacia in Northern India, not much work on vitamin D was carried out prior to 1940. Basu and Sen Gupta (1940) first studied the vitamin content of liver oil of a few common fresh water fishes and found very little amount of vitamin D in them as compared to cod liver oil.

Ranganathan (1941) analysed shark liver oil and found it to contain about 200 IU of vitamin D per g. Since shark liver oil had

to be diluted before marketing, it was considered necessary to fortify the oil with vitamin D to bring it up to the BP standard for cod liver oil.

Niyogi, Patwardhan and Acharya (1943b) found that the vitamin D content of *mushi* and *ghol* determined by the bone-ash method was 97 IU and 575 IU per g. respectively.

The blood serum values of 79 cases of suspected or frank rickets in infants and children and 11 normal children were analysed for calcium, inorganic phosphorus and total proteins by Patwardhan, Chitre and Sukhatankar (1944). pk s.p. values of $CaHPO_4$ and $Ca_3(PO_4)_2$ were found to be 5·7 and 23·0 respectively in 77 cases of rachitic children. In case of non-rachitic children in only one case the value of the former was above 5·7 and two cases were unsaturated in case of the latter salt. In another study, Patwardhan and Chitre (1942) did not find any evidence of any direct influence of vitamin D on the absorption of calcium from the intestines of albino rats. The observations were made on normal, rachitic rats as well as on the rats with induced hypervitaminosis D, by the isolated loop technique.

An attempt was also made by the Indian Institute of Science, Bangalore, to prepare liquid calciferol from irradiation of ergosterol obtained from yeast. A company in Kasauli attempted to manufacture large quantities of malt extract with vitaminised oil from indigenous materials to replace cod liver and malt extracts which were in very short supply.

Vitamin B Complex: The factors which have mostly been studied in India are aneurin (B_1), riboflavin (B_2), nicotinic acid and pyridoxine (B_6).

Aneurin (Vitamin B_1) : Attempts were made to prepare vitamin B_1 from indigenous sources. Successful attempts were made to culture the particular species of yeast (Torula yeast) required for preparation of these substances. Attempts were also made to prepare the yeast extract from the Brewer's yeast, and the Biochemical Standardisation Laboratory (now Central Drugs Laboratory) succeeded, on a small scale, to prepare satisfactory preparation. Swaminathan (1942) found that there was very little difference in vitamin B_1 content between Torula yeast and Brewer's yeast. The same author (1942) also studied the effect of washing and cooking on the vitamin B_1 content of raw and parboiled milled rice, and found that raw rice lost about 60 per cent. of its total vitamin during washing, whereas parboiled rice lost only 8 per cent. when similarly washed. He has thus shown that washed parboiled rice contains about four times as much vitamin B_1 as washed raw rice. This observation obviously is of great value as it indicates the amount of loss of vitamin B_1 during the process of cooking of rice in the common Indian kitchen.

Riboflavin (Vitamin B_2) : Not much work seems to have been done on this vitamin in India. Biswas (1940) found that vitamin B_2 content of white flour was higher than of *atta*. The occurrence of mouth lesions is very common in riboflavin deficiency. In an established case of ariboflavinosis, Vakil (1945) noticed typical vulval lesions in addition to oral lesions, both of which disappeared on administration of riboflavin. Few cases of angular conjunctivitis showing numerous

Morax-Axenfeld bacilli in the smears were successfully treated by Verma (1944) by administration of riboflavin. The bacilli disappeared after treatment. Swaminathan (1942) estimated the riboflavin content of some of the common foodstuffs and human urine. He found dried yeast to be a rich source while other foods were generally poor. The normal daily output of the vitamin in the human urine was found to be 320-360 μg. After ingestion of test doses of riboflavin, 80-85 per cent. of the test dose was found to be excreted during 24 hours. Basu and Nath (1942) have postulated the relationship of riboflavin to the utilisation of proteins.

Nicotinic Acid : Many workers have studied the nicotinic acid contents of various cereals. Aykroid and Swaminathan (1940) tried to associate pellagra with maize. They found that maize, raw milled rice and millets contained the minimum amount of nicotinic acid (1·0-2·0 mg./100 g.), whereas whole wheat was richest in this factor (5·0 mg.). Home-pounded raw and parboiled rice, milled parboiled rice and barley contained 2·5-4·0 mg./100 g. Swaminathan (1942), by a simpler and more economic technique, found that yeast contained the highest amount of this vitamin (44·5 mg.), and vegetables contained the lowest amount (0·2 mg.). Khorana, Sarma and Giri (1942) estimated the nicotinic acid content of various fishes and found that majority of them contained this vitamin to the extent of 2-4 mg./100 g., the highest value being in *Hilsa* (4·7 mg.). Braganca (1944) observed that the sea water fishes contained higher amount of this vitamin than the fresh water ones, the highest amount being in pomfrets (3·1 mg./100 g.). Swaminathan (1944) analysed a large number of Indian foodstuffs, and found that dried Brewer's yeast, liver and rice polishings were very rich in nicotinic acid, the content being 44·5, 15·3 and 25·4 mg. per 100 g. respectively. Whole wheat, unmilled rice, whole barley and parboiled rice are also good sources and contain twice or thrice of the vitamin content of foodstuffs like wheat flour, maize, oatmeal, raw milled rice, milk, eggs, vegetables and fruits. These observations are of great value to the dietician in the planning of the diet for the troops.

Kochhar (1940) estimated the amount of nicotinic acid in the blood of normal men and found the value to be 300-400 μg. per 100 cc. He also observed (1941) that most of the nicotinic acid of blood was present in the red blood cells. He found no variation in the nicotinic acid content of blood in cases of pellagra and thus concluded that estimation of this vitamin in blood was of no value in the diagnosis of pellagra.

Ghosh (1941) determined the output of this vitamin in the urine of healthy adults and found the value to be 3·0-5·3 mg. in 24 hours. He also observed that the vitamin in urine gets destroyed at room temperature by bacteria. The destruction is quickest at pH 3·0-5·0 and it is more stable at lower or higher pH. Preservation of the urine with alcohol or toluene rendered the vitamin more stable.

Excretion of nicotinic acid in the urine by the patients suffering from pellagra had also been studied to a great extent. Naganna, Giri and Venkatesam (1941) found the amount negligible, but when the

patients were treated with nicotinic acid, the output gradually returned to normal with disappearance of the pellagra symptoms.

Aykroid and Gopalan (1945) studied few cases of chronic, non-infective, non-fatty diarrhoea associated with emaciation and microcytic anaemia. They found that the condition responded rapidly to administration of nicotinic acid.

Pyridoxine (*Vitamin B_6*) : As in the case of riboflavin very little work was done in India on pyridoxine during the war. Swaminathan (1940) devised a very sensitive chemical method for the estimation of this vitamin in the foodstuffs. By employing his method he found that dried Brewer's yeast, rice polishings and sheep's liver are very rich sources of vitamin B_6. Cereals and pulses contain fair amount but the vegetables are a very poor source. The same worker (1941) estimated the output of this vitamin in normal urine, and found the value to be 400-560 μg. in 24 hours.

Vitamin C : Quite an extensive study has been made on this vitamin on account of its simplicity. Mitra K, Mittra H. C., and Roy (1940) estimated the ascorbic acid content of a large number of common vegetables and fruits and found that most of the vegetables contained more than 100 mg. per 100 g., the richest source being the tender leaves of gram (200 mg.).

By 1942, the demand for vitamin C preparations by the War Department rose to considerable proportions. It was found that dried Indian gooseberry (*amla* powder) was a very rich source of ascorbic acid, and tablets containing 25 mg. of vitamin C were prepared from this substance by Coonoor Nutritional Laboratories, and supplied to the Indian Army. It was later found that the vitamin was somewhat unstable in this preparation and the potency of these tablets deteriorated rapidly. It was, therefore, considered necessary to use the dried stuff in very large amount. With a view to concentrating the vitamin, Sastri and Sivaramakrishnan (1942) developed an absorption technique of obtaining concentrates from *amla*. Russian workers had reported that pine needles were a cheap and rich source of ascorbic acid. On these reports Iyengar, Bose and Mukerji (1944) estimated the ascorbic acid content in the pine needles of Simla hills. Palatable syrups were prepared from the pine needle extracts containing ascorbic acid. Pause and Srinivasan (1945) found that leaves of drumstick tree (*Moringa oleifera*) were a very rich source of this vitamin (900-1,100 mg./100 g.). They observed that the watery extracts of the leaf are stable when obtained during the period of maximum vegetative growth but when the tree is flowering, almost 80 per cent. of the vitamin is lost during extraction due to development of oxidase system in the leaf.

While studying the potency of vitamin C in milk, Kothavala and Gill (1943) found that about 23 per cent. of the vitamin was destroyed by first boiling, 60 per cent. by 10 minutes boiling and almost 100 per cent. by boiling for 20 minutes. There was certain amount of destruction of the vitamin on exposure to sun light and on pasteurisation. Milk handled and processed in commercial dairies generally lost 50-60 per cent. of its vitamin C content.

An intensive study has been made by Banerji (1940) on the estimation of vitamin C in the urine. He found that sulphuric acid is a better preservative for urinary ascorbic acid than glacial acetic acid commonly employed. Banerji, Sen and Guha (1941) also studied the role of ascorbic acid in infection. They found that in pulmonary tuberculosis a large portion of the administered ascorbic acid is excreted in a combined form. If, however, heavy doses are administered over prolonged periods, combined ascorbic acid disappears from the urine. They thus suggest that ascorbic acid has a detoxicating function both in normal and in infective conditions, by combining with toxins and toxic metabolites and eliminating them in this manner. The disappearance of combined ascorbic acid after continued intake of large doses indicates that the metabolism was normal and no more abnormal metabolites were present. Ghosh (1944) observed that detoxicating capacity of ascorbic acid is selective. He found that mechanism of detoxication involved the excretion of some ascorbic acid in a combined state in the case of organic poisons but not in the case of inorganic substances.

Basu and Ray (1940a) found the normal output of ascorbic acid to vary between 2·4-14·7 mg. in 24 hours. They also studied the excretion after its intake in large doses and found that until a state of saturation was reached the increase in the output was negligible. After saturation the output rapidly rose and it represented a varying percentage of the total intake, but never equalled the intake. Basu and Ray (1940b) also studied the effect of ascorbic acid on skeletal muscle in human subjects and showed that after saturation with ascorbic acid, the onset of fatigue was very much delayed. This observation obviously has some practical application on the efficiency of the troops.

ENZYMES

Extensive work was done during the war years in the field of enzymes. Rudra and Roy (1940) studied the changes in serum phosphatase activity in persons suffering from pulmonary tuberculosis, and found that in such patients the activity of the alkaline phosphatase is higher than normal. They have also shown that administration of ascorbic acid to these patients lowers the phosphatase value side by side with improvement in the clinical condition. From these observations they have suggested that determination of serum phosphatase activity may be carried out as a routine for evaluating the clinical progress of tuberculous patients. Giri (1939) has also made extensive studies on the effect of vitamin C on phosphatases. He has shown that the activities of alkaline and acid phosphatase of kidney, liver and brain are inhibited by the vitamin C-copper complex. Neither vitamin C nor copper alone has any effect on their activities. Giri (1940) has also shown that vitamin C protects liver phosphatase from destruction by unfiltered ultra-violet radiation.

Chitre (1943) investigated the serum alkaline phosphatase activity in patients with bone tumours. He observed that there was no increase in the activity of the enzyme in cases of benign giant-cell tumour and in Ewing's tumour. There was definite increase only in a few cases of

osteogenic sarcoma, and in some cases of cancer with secondary metastasis. In all cases decrease in the activity was observed after operation.

Ahmad, Sehra and Swaroop (1945) investigated the blood conditions of people living in Kangra Valley, Punjab, where there was very high incidence of rickets and osteomalacia. They found that in such patients serum phosphatase activity remained within normal limits and did not rise markedly as is found in literature. They suggested that rise of phosphatase activity would occur only in those cases where there is deficiency of phosphorus in the body and not in patients suffering from high phosphorus and low calcium rickets.

While experimenting on guinea-pigs, Roy (1944) observed that in scurvy there was marked lowering of activity of serum and bone phosphatase, whereas phosphatase activity of other tissues was very slightly affected. He in collaboration with Sen (1944) studied the effect of starvation on the alkaline phosphatase activity of tissues of guinea-pigs and the influence of carbohydrates, fats and proteins on the regeneration of the enzyme. They found that starvation markedly reduced the phosphatase activity of tissues and serum and that the response of the phosphatase to the different dietary factors was not uniform. They concluded that the nature of the enzyme complex in different tissues differs qualitatively, and that the various components of the enzyme complex are stimulated to a varying extent by the different dietary factors.

A micro method for detection of phosphatases in extracts and tissues has been described by Das, Giri and Rao (1946). In this method a drop of the extract or a thin strip of the tissue supposed to contain phosphatase is placed in a petri dish containing agar, buffer and sodium phenolphthalein phosphate. The plate is incubated for a varying period, at the end of which the plate is flooded with N/10 NaOH. The presence of phosphatase is indicated by the formation of a red zone due to liberation of phenolphthalein from sodium phenolphthalein phosphate by the enzyme. The width of the coloured zone is roughly proportional to the concentration of the enzyme in the solution.

Sehra, Chopra and Mukerji (1941) studied the changes in serum phosphatase activity in liver damage and in biliary obstruction. In both conditions high values were obtained, more in biliary obstruction than in liver damage.

Extensive studies have been made by Iyengar (1942a) on the proteolytic system present in the blood. He has shown the presence of a trypsin-kinase in platelets capable of liberating the trypsin from the trypsin-inhibitor compound present in blood plasma. He also studied the effects of trypsin-inhibitors of blood on the activity of trypsin. It has been shown that there is a significant rise in plasma trypsin immediately after an operation. He suggested that plasma trypsin possibly performs the function of thromboplastin circulating in the blood. Iyengar (1942b), however, proved that though trypsin-kinase and thrombo-kinase are both present in platelets and trypsin and thromboplastin have similarity in certain respects, these are two separate entities.

Free and total plasma trypsin content of the plasma in various pathological conditions were determined by Iyengar, Sehra and Mukerji (1942), and they found that total trypsin content of the plasma were constant in all cases. There was, however, a diminution in the free plasma trypsin content in cancer and an increase in diabetes mellitus and nephritis. Both the total and free trypsin were practically absent in anaemia and thrombocytopenia purpura. A rationale of the treatment of cancer by cobra venom was suggested by them on the observation that there was an increase in plasma trypsin content after administration of cobra venom, the increase being due to release of trypsin by the venom from the tissues into the blood, whereas there is diminution of plasma trypsin in cancer.

During the war, to meet the increased demand of cheese by the Defence Services, many workers were engaged in finding a suitable milk-coagulating enzyme of purely vegetable origin for use in the manufacture of cheese. Narain and Singh (1942) studied the milk-clotting enzyme in various plants and selected *Withania coagulans* for the preparation of rennet as it is easily available and contains a very active enzyme. They observed that cheese obtained by using the preparation of vegetable rennet was as good as that prepared with animal rennet. The cheese thus prepared was found satisfactory for the hospital requirements of the armed forces.

BIOCHEMICAL CONSTITUENTS OF BLOOD AND FUNCTIONAL CAPACITY

Many workers attempted to determine the average normal values of different biochemical constituents of blood and functional capacity of different systems of Indians. Gokhale (1939) during his study of non-protein nitrogenous constituents of blood found that the ratio between total urinary nitrogen excretion in 24 hours in g. and the blood urea nitrogen in mg. per 100 cc. of blood was 1 : 2 instead of 1 : 1 as reported by European and American workers. This was due to the fact that total urinary nitrogen excretion amongst Indians was about half that of European and American subjects, though the blood urea nitrogen was the same. Gokhale (1941) determined the blood urea clearance of a large number of healthy Indians and found the average maximum clearance as 44 cc. and standard clearance as 33·8 cc., values which are definitely lower than those reported by American workers.

Ram (1944) determined the pH values of urine of healthy subjects and found that the average was 7·60, the maximum and minimum being 7·18 and 8·01 respectively.

Blood cholesterol content amongst Indian women was studied by Nayar (1942), who found lower values amongst Indian women than amongst Europeans. He observed diminution of the value in anaemias but not in proportion with RBC count and the haemoglobin level. Further lower values were obtained in bacterial, protozoal or helminthic infections.

Mangalik V. S., Goel and Mangalik, H. (1942) using different meals in the fractional test meal analysis observed that alcohol was the best gastric stimulant and it did not cause an initial decrease in acidity after administration. No difference in response was seen between vegetarians and meat eaters. They also found that hyperchlorhydria was more common in men than in women and it increases with age. Of the cases studied 6 per cent. showed a histamine fast achlorhydria. Bhende (1942) found that some cases of tropical macrocytic anaemia were histamine refractory, and Chopra and Chakravarty (1942) reported hyperacidity to be common in chronic ulcerative colitis.

Attempts were made to study liver function tests in different diseases. Pai (1941) performed Takata-Ara tests in a large number of cases with cirrhosis of liver and found positive reactions in most of them. Some of the controls which also gave positive reactions showed liver damage later.

While studying various factors influencing glycolysis in blood, Bose and De (1942) observed that in defibrinated blood, loss of sugar was maximum in shortest time, and the rate of glycolysis increased in proportion to temperature. It was high when potassium oxalate was used as the anticoagulant, and low with fluoride. They also found that non-glucose reducing substances in the blood amounted to 25 mg. per 100 cc. of the blood.

Iyengar, Sehra and Mukerji (1941) have modified Quick's method of determining prothrombin time by adding directly to the plasma 0·2 cc. of 1 in 20,000 solution of Russell's viper venom solution in 0·025 M $CaCl_2$. This method slightly speeded up the prothrombin time. Reddy and Venkataramiah (1941a) by employing Quick's method showed that excess of calcium prolongs the prothrombin time in direct proportion. They (1941b) found that using M/10 $CaCl_2$ solution, the normal limits are 40-60 seconds, and with M/40 solution, the limits are 15-20 seconds. The time is prolonged in obstructive jaundice and cirrhosis of liver. Rahman and Giri (1945) further modified the method of determination of prothrombin time in blood plasma by using Russell's viper venom. The thromboplastic potency of the venom solution was found to be very stable at low temperature. It could be kept at 5° C. for nearly six months without any loss in the potency. They found the prothrombin time of normal healthy persons to vary from 8 to 13 seconds. A markedly prolonged time was observed in cases of tuberculosis, anaemia, malaria, jaundice and during pregnancy.

A large number of stools from patients with active, convalescent or suspected sprue were analysed by Black and Fourman (1945). They found that quite a large proportion of the samples with high fat content showed neither pallor macroscopically nor any fatty acid crystals on microscopic examination. They were, therefore, of opinion that chemical analysis is necessary to know with certainty whether a stool contains an excess of fat or not. Macroscopic or microscopic examinations to determine the same were not enough.

AGAR AGAR, PEPTONE AND STAINS

Biochemical researches were also carried out in various other spheres, e.g., in the manufacture of different chemicals and drugs, in the improvement of laboratory techniques, etc.

Agar Agar: Prior to World War II, India was dependent on Japan and other foreign countries for the supply of agar agar required extensively for bacteriological work and for the manufacture of vaccines. Early in 1940, due to stoppage of supply from outside, necessity of manufacturing this substance in India was acutely felt, and under instructions from the DGIMS manufacture of agar agar from Ceylon moss was started at the Medical Stores Depot Factory, Madras by a method worked out by Dr. J. N. Ray. The supply of Ceylon moss being not sufficient, a new source of the raw material had to be explored, and Chilka lake *Gracilaria* was found to be another suitable source. Karunakar, Raju and Varadarajan (1944) have described a simple method for the manufacture of agar from the seaweed *Gracilaria lichenoides* found in plenty in the Chilka lake. The yield was about 20 per cent. by this method, and the agar thus prepared conformed to the BP standard. Attempts were also made to utilise the agar from used agar media. Roy and Ray (1944) described a method by which the recovery was about 50 per cent. and the recovered agar was suitable for bacteriological work. A 3 per cent. solution of this product was enough to give a film of good surface and consistency for the vaccine bottles.

Peptone: Peptones used for bacteriological purposes were all imported from abroad and when this was stopped, attempts were made by a number of manufacturing concerns to manufacture this substance. The suitability of these products for various bacteriological tests as well as for the manufacture of vaccines was examined by the Central Drugs Laboratory and the CRI, Kasauli, and several samples were found to be satisfactory and were accepted for general use.

Stains: Due to acute shortage of stains for bacteriological work, an attempt was made by the CRI to prepare the stains by purification of the commercial dyes available. Several stains, e.g., chrysoidin, crystal violet, eosin, basic fuchsin, Leishman, Giemsa and methyl violet were prepared at the institute and the Biochemical Standardisation Laboratory found them to be of approved quality. The difficulty in obtaining supplies of neutral acetone-free methyl alcohol at reasonable price for the preparation of blood stain led the workers at the CRI, Kasauli, and Drugs and Dressing Directorate, Directorate General of Supply, to find out if absolute ethyl alcohol could be used in place of acetone-free methyl alcohol. The results of these investigations are summarised below :—

(i) The use of expensive acetone-free methyl alcohol for the preparation of blood stains as specified in literature is only incidental and not very necessary.

(ii) Absolute ethyl alcohol can be a good substitute for the expensive acetone-free methyl alcohol in the preparation of stain solutions required for simultaneous fixation and staining of blood.

(iii) Even 95 per cent. alcohol can be used in the preparation of solutions of Giemsa type where fixation of thin smears is done separately and thick smears are unnecessary.

(iv) Ethyl alcohol, in the preparation of Leishman type solution for staining at higher atmospheric temperatures, is definitely superior in use to the volatile methyl alcohol.

HORMONES

Due to difficulty in import, an acute scarcity of a number of glandular preparations, e.g., adrenaline, pituitary extract, insulin and liver extract, was felt and an all out effort for the manufacture of these products in India was made. In Calcutta large quantities of pure adrenaline tartrate were prepared from the suprarenal glands of the animals slaughtered in the city abattoirs. The Indian Institute of Science, Bangalore, manufactured large quantities of posterior pituitary extracts. Attempts to manufacture insulin were, however, not successful, although small quantities of crude insulin solutions were made.

DRY PLASMA

The imminent possibility of air attacks by the Japanese in 1942 necessitated the immediate organisation of blood banks for the collection and storage of blood plasma for use in transfusion. The difficulties of stocking large quantities of plasma in satisfactory condition were realised and attempts were made for preserving it in dry and stable form. Colonel Hayes and Dr. J. N. Ray investigated the problem in the research laboratory of the Punjab University and a workable process was discovered. The production of plasma was subsequently undertaken by the All India Institute of Hygiene and Public Health in Calcutta.[6] Dyer, Sankaran and Subrahmanyan (1943) designed a plant for drying plasma from the frozen state in a very high vacuum. They were thus able to produce a dry powder with moisture content of less than 1 per cent. and with high solubility. There were, however, innumerable difficulties in the constant use of the machine for continuous production. Krishnan and Narayanan (1944) worked out a chemical method of preparing dry plasma proteins for transfusion purposes. This method is based on the fact that by the addition of alcohol or acetone to plasma at a temperature below 5° C., the proteins can be completely precipitated without denaturisation and the precipitate treated with cold ether can remove any trace of alcohol or acetone. Krishnan, Mukerji and Dutta (1944) evolved an experimental technique for testing these products on cats and found them to be satisfactory for parenteral use.

PROTEIN HYDROLYSATE

The urgent demand for transfusion material for combating shock and hypoproteinaemia made it necessary to look for cheaper and more easily prepared substitutes. Elmer and Lischer (1943) reported

[6] See also page 785.

that in severe surgical shock experimentally produced by repeated haemorrhage immediate transfusion of a solution of hydrolysed protein containing amino-acids and polypeptides exerted a definite therapeutic effect. Narayanan and Krishnan (1944) have been able to prepare protein hydrolysate by digesting meat with papain at 50° C. for 24 hours. The filtrate was made suitable for intravenous injection by removal of the undigested proteins and metaproteins by repeated heat coagulation. Glucose and sodium chloride were added to get a mixture containing 5 per cent. protein hydrolysate, 5 per cent. glucose and 0·85 per cent. sodium chloride. The mixture was finally sterilised in transfusion bottles. The Central Drugs Laboratory tested the product and found that it was safe for transfusion and that its value in the treatment of shock was midway between that of serum and of glucose saline. Krishnan, Narayanan and Sankaran (1944) have reported the results of administration of this preparation to advanced cases of starvation who were in moribund state and were unable to take fluids by mouth. Results on the whole were very satisfactory. Viswanathan (1945) has reported the use of protein hydrolysate in infective conditions. These encouraging reports resulted in the manufacture of this substance for oral and parenteral administration on a large scale. Iyengar, Biswas and Mukerji (1946) have worked out the various tests and standards by which the purity and therapeutic utility of these preparations could be checked and controlled.

CALCIUM GLUCONATE FROM SUGAR AND MOLASSES

The process for making calcium gluconate from sugar and molasses was developed by Dr. J. N. Ray and Mr. Mansa Ram of the Directorate General of Supply. As the Council of Scientific and Industrial Research had given a small grant for the experiment, a patent was taken by the Council of Scientific and Industrial Research and sold to a firm at Calcutta. Calcium gluconate was produced by fermentation process and conditions for efficient fermentation of molasses in the presence of suitable ferments were established so that the process might be worked out on a commercial basis. Large quantities of calcium gluconate were produced by the firm by adopting this process and supplies were made against Government demands.

IMPROVEMENTS IN LABORATORY TECHNIQUES

Biochemical knowledge about the end products of protein and amino-acid metabolism and the selective utilisation by bacteria and vibrios of these products led to the elaboration of a number of laboratory methods which played a great part in diagnostic laboratory work during the period of war. Sokhey and Habbu (1944) investigated the possibility of preparing an effective cholera vaccine from growths on the acid hydrolysates of casein. The medium, which was easy to prepare, was found to give a profuse growth of the vibrio and did not give the 'biuret' reaction. The cost of production was much lower than by the usual method of preparation of the cholera vaccine.

In addition, the vaccine in this medium was found to have lower toxicity than usual. Panja (1942) described a new method of isolation of vibrios from stool of cholera cases by using boric acid (0·08 per cent.)—peptone water at pH 9 and filtering the mixture through a L3 porcelain candle. Boric acid was found to inhibit the coliform organisms but not the cholera vibrios. This simple biochemical reaction gave a higher percentage of isolation of vibrios from cholera stools. Acting more or less on the same principle, Basu, Sen and Sen Gupta (1945) developed a culture medium from ground-nut meal by digesting the protein matter of the meal with activated papain. In this way a good yield of broth was obtained which could be used as culture medium in the bacteriological laboratories.

In view of the fact that the acid haematin standards usually employed in the estimation of haemoglobin did not last very long due to gradual fading of the colour, attempts were made by the Central Drugs Laboratory and the CRI, Kasauli to prepare a stable artificial standard for haemoglobin estimation. After some successful attempts, using hydrolysed ferric chloride, the work was discontinued as large number of satisfactory glass standards were soon available from the USA.

BASAL METABOLIC RATE (BMR)

The study of the caloric intake in relation to the basal and total metabolic needs of an individual is obviously of very practical importance. Although the investigations on basal metabolism are strictly physiological studies, reference to them may be briefly made here. Patwardhan (1944) reviewed the subject, based on investigations done in various laboratories in India on 372 men, 151 women and 97 boys, and observed as follows:—

(i) The series averages for males vary from 34·26 Cal/m²/hr. to 36·7 Cal/m²/hr. This difference is mainly due to the calculations of series averages by different authors from (a) the first satisfactory determination or the averages of the first day readings leading to the higher value or (b) the lowest reading or the averages of two or three lowest readings leading to the lower value for series averages. The difference in technique and apparatus has contributed little, if any, to the discrepancy. If the series averages are calculated uniformly on the first or lowest readings the differences between the values would decrease to about 2 per cent.

(ii) The series averages for females vary within very narrow limits of 30·9 to 32·05 Cal/m²/hr.

(iii) The discrepancy in the results of investigations on boys at Calcutta and Bombay is too great to be explained on any of the above considerations.

The various factors held responsible for the low BMR of Indians have been examined on the strength of the available evidence and the following conclusions appear justifiable.

(i) The physical and physiological measurements on the subjects do not indicate any abnormality. The subjects were not undernourished except probably the boys studied by Wilson and Roy.

(ii) No evidence is forthcoming to show that the low BMR was due to the low nitrogen metabolism of Indians. An experimentally produced short term rise in the nitrogen metabolism was not accompanied by any rise in BMR of ten male subjects. Moreover, the protein intake of Indians of the class subjected to BMR studies was not found low when investigated. The utilisation of the protein was rather poor.

(iii) The influence of the tropical climate on BMR would probably account for at least a 5 per cent. fall of the latter.

(iv) Since an average fall of BMR of about 10 per cent. has been observed during sleep in the Indian subjects, it cannot be said that the low BMR in Indians is due to a lower muscle tone than that which exists in Europeans and Americans.

(v) If the surface areas as actually measured should be found to be smaller than that obtained by the height-weight formula the revised values of BMR might become slightly higher than what they are at present.

All the evidence accumulating in India and outside points to the existence of a racial factor influencing the BMR. In case of Indians, an allowance of a lowering of BMR by 5 per cent. due to the tropical climate can probably be made. The remaining difference from the Aub-Dubois or Harris-Benedict standards may be considered to be probably due to the racial factor.

During an examination of the factors influencing the basal metabolism, Niyogi, Patwardhan and Sirsat (1941) observed as follows :—

(i) A high protein intake and an increased nitrogen elimination are not accompanied by an increase of basal metabolism.
No significant differences were observed in the BMR of strictly vegetarians and that of non-vegetarians.

(ii) The average creatinine coefficient of adult males in Bombay is practically the same as that of the Westerners and yet their basal metabolism is low.

(iii) Individuals with low creatinine coefficient do not show a low metabolism.

(iv) The level of basal metabolism seems to be uninfluenced by the normal variations in blood pressure, vital capacity and pelidisi.

(v) In Bombay the difference of temperature and humidity of the atmospheric air is not very great during the different seasons and although no marked change of metabolism has been noticed during the year there appears to be slight increase of metabolism in the summer months when the atmosphere is hot and humid.

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CHAPTER XLI

Pathology and Research

The pathology organisation of the pre-war years consisted of a DDH and P (senior lieut.-colonel or colonel) and an assistant director of hygiene and pathology (ADH and P) at GHQ, an ADH and P (lieut.-colonel) in each command, a DADP (major) in each military district, and an officer-in-charge (major or captain) in each brigade laboratory. There were 26 laboratories including the Enteric Laboratory, Kasauli, the Southern Command Laboratory, Poona, 12 district laboratories and 12 brigade laboratories. There was also a Military Food Laboratory at Kasauli. In addition to the officers, the laboratories had the necessary subordinate personnel, including assistant surgeons, Indian (IC) and British cadres (BC), RAMC laboratory assistants and IHC clerks, ward servants and sweepers.

The DDH and P at GHQ advised the DMS in India on all questions relating to the administration of laboratories and maintained contact with ADsH and P of commands and with DADsP of districts. The ADH and P and DADP likewise were advisers to their DDsMS and ADsMS respectively.

The sanctioning and nominating authority for the appointments of DDH and P, ADH and P was the Commander-in-Chief, while officers-in-charge of the Enteric Laboratory, and brigade laboratories were appointed by the DMS in India.

The Enteric Laboratory and Military Food Laboratory at Kasauli were under the direct administration of the DMS in India. The Southern Command Laboratory, Poona, was administered by the DDMS, Southern Command. The district and brigade laboratories were administered by the ADMS of the district in which they were located.

District Laboratories : The DADP was also personally in charge of the district laboratory. The district laboratories were located at Peshawar, Rawalpindi, Lahore, Quetta, Meerut, Secunderabad, Kohat, Razmak, Lucknow, Calcutta, Colaba and Bangalore. The DADP supervised the technique and laboratory methods employed in brigade laboratories and the clinical side rooms of hospitals and was responsible for training the subordinate staff (assistant and sub-assistant surgeons) in laboratory methods. The DADP prepared and submitted an annual pathology report. He was also called upon to assist in carrying out duties in the hospital at which the district laboratory was located, but only under exceptional circumstances.

Brigade Laboratories : Brigade laboratories were located at Sialkot, Ambala, Bannu and Abbottabad in the Northern Command, at Dehra Dun, Bareilly, Jhansi, Allahabad and Delhi in the Eastern Command, and at Nasirabad, Mhow and Jubbulpore in the Southern Command. The officer-in-charge, brigade laboratory, carried out bacteriological and pathological work and was in addition available for hospital duties. He kept in touch with the DADP of the district in all matters affecting

the work of the laboratory and submitted annually a report of the work done in the laboratory.

Clinical Side Rooms : Clinical side rooms were authorised for Indian and British military hospitals of 50 beds and over and were meant for examination of blood films, sputum, urine and other material by officers in medical charge of cases.

Wassermann Tests : The Southern Command Laboratory, Poona, and the district laboratories at Rawalpindi, Quetta and Meerut carried out Wassermann tests.

PATHOLOGY ORGANISATION IN INDIA DURING WORLD WAR II

The peace time pathology service of the Army in India could not keep pace with the large increase in the number of hospital beds. Some large stations were without any laboratory facilities, except those available in the hospital clinical side rooms. By the end of 1942, it was realised that existing pathology service was only adequate for public health work alone and could not be successfully applied to clinical pathology work which constituted the greater part of the work of military laboratories. The pathology service, therefore, was reorganised and considerably expanded.

The reorganisation included the formation of a central consultative and training laboratory, re-arrangement of existing district laboratories in order to meet the concentration of large hospitals, formation of a station laboratory in every station in India with 250 or more equipped hospital beds, formation of a Wassermann laboratory in each special venereal disease hospital, appointment of one ADP to each army/command and replacement of the appointment of DADP in a district laboratory by an officer-in-charge, district laboratory.

With increase in the volume of work created by war conditions, it was found necessary to split the appointment of ADH and P at the GHQ into two separate appointments—ADP and ADH. The appointment of ADH was, therefore, created in April 1941, and later on the existing appointment of ADH and P was redesignated as ADP with effect from 25 February, 1942.

In the commands, it was not possible for the ADH and P to effectively administer both the hygiene and pathology branches, after the reorganisation of both these branches and the huge expansion of the Indian Army. An ADP already existed in the Southern Army. On 17 June 1943, orders were issued sanctioning the appointment of ADP at Headquarters North Western Army, Eastern Army and Central Command. The appointment of an ADH to each of these formations was also authorised. The appointment of ADH and P at headquarters of these formations was then abolished.

Interim Peace Establishment for Military Laboratories in India : There was no fixed establishment for district or brigade laboratories and personnel were provided according to requirements of each individual laboratory. The adoption of the following interim peace establishment

for military laboratories in India was accordingly sanctioned on 18 October 1942.

Personnel	Enteric Laboratory Kasauli	Army/ Command Laboratory	District Labora-tory	Brigade Labora-tory
Lieut.-Colonel IMS or RAMC	...	1	...	...
Majors, IMS or RAMC ...	1	...	1	...
Captain or lieutenant, IMS, RAMC or Indian Medical Department (IMD) ...	...	...	...	1
Assistant surgeons IMD (British Cadre) (BC) ...	1	1	...	...
Assistant surgeons IMD (Indian Cadre) (IC) ...	1	1	1	1
Laboratory attendants, Class I, RAMC ...	2	1	1	...
Laboratory assistants (civilian)	2	...	...	...
Ward servants, grade I ...	2	3	2	1
Ward servants, grade II ...	...	1	1	1
Sweepers, grade I ...	2	3	2	1
Sweepers, grade II ...	1	1	1	...
Carpenter	1	...	...	...
Clerical havildar, grade I ...	...	1	...	...
Clerical havildar, grade II ...	1	...	1	...
Clerical havildar, grade III ...	1	...	...	1
Peon	1	...	...	1

Central Military Pathology Laboratory : The formation of a central laboratory was considered essential, since the efficient training of staff for lower formations depended on it. Instead of raising a separate unit, it was proposed to expand the existing Southern Army Laboratory.

The Central Military Pathology Laboratory, Poona, was formed on 17 June 1944, by the amalgamation of the Enteric Laboratory, Kasauli, and Southern Army Laboratory, Poona. The staff of the laboratory was increased to four officers, including a bacteriologist, a histo-pathologist, a biochemist and a serologist. The following establishment was authorised for this laboratory:—

Lieut.-Colonel, IMS or RAMC	1
Major, captains or subalterns, IAMC or RAMC ...	3
Conductors IAMC	2
Quartermaster sergeant RAMC	1
Sergeants, RAMC	2
Subedars, IAMC	2
Laboratory assistants [(Staff Sergeant, WAC(I)] ...	2
Clerical havildars, grade II	2
Clerical havildars, grade III	2
Ward servants, grade I	5
Ward servant, grade III	1

Sweepers, grade I	2
Sweeper, grade II	1
Carpenter	1
Peon	1

The Central Military Pathology Laboratory became the main teaching centre for clinical pathology, for both officers and other ranks. It also became the consultant laboratory for the India Command, and was available for expert opinion and technical advice in all matters connected with laboratory diagnosis of diseases. The laboratory was also responsible for the preparation of biological products for the use of the armies in India, Burma and ALFSEA.

The ADsP armies/commands maintained close liaison with the officer commanding, the Central Military Pathology Laboratory, and were required to ensure that full use of the facilities available there was being made by all military laboratories.

District Laboratories : There was no increase in the number of district laboratories until the middle of 1942. A district laboratory at Shillong was sanctioned on 31 December 1942 by expansion of 'M' Section of the local Pasteur Institute. The appointment of DADP at Headquarters Eastern Army and Central Command, as well as the 12 DADP appointments at district headquarters in India, were abolished on 17 June 1943. The district laboratories continued to work at Karachi, Peshawar, Meerut, Bombay, Ranchi, Quetta, Lahore, Lucknow, Bangalore, Razmak, Rawalpindi, Calcutta and Shillong. On 9 July 1943, additional district laboratories were authorised at Secunderabad, Deolali South and Moradabad. The following revised establishment was also sanctioned for a district laboratory :—

Major, captain or subaltern, IAMC or RAMC (specialist in pathology)	1
Subedar, IAMC (Special Medical Section) laboratory asstt.	1
Sergeant, RAMC (laboratory attendant class I) ...	1
Clerical havildar, grade III	1
Ward servants, grade I	2
Ward servant, grade III	1
Sweeper, grade I	1
Sweeper, grade II	1

The main result of this reorganisation was that the appointment of DADP was abolished and district laboratories were placed in charge of officers who were treated like other specialists in the medical service. The officer-in-charge, district laboratory was directly under the ADMS of the district and advised him on all technical matters, but was not on his staff. On purely technical matters he could communicate with the ADP army/command. He was not expected to do any executive duties in hospital but was required to inspect all station and field laboratories and hospital clinical side rooms in his area, and arrange to supply these with such stains and reagents which required special equipment for preparation. He lectured to junior medical officers in the station, at least twice a month, on laboratory investigation of diseases and collection of suitable specimens. He was also required to maintain personal liaison,

specially with the medical specialists, in order to ensure close co-operation between clinical and laboratory work, and to render an annual return of all the work done in the laboratory and to submit an annual report on pathology.

Station Laboratories : In order to conserve medical manpower, it was considered desirable to authorise laboratories on a slightly lower scale and to employ as many commissioned women doctors in them as possible. The number of brigade laboratories had increased from the peace time 12 to 16 in July 1942. One of these laboratories was, however, disbanded soon after July 1942. A provision was made for a selected VCO of the IMD (IC) to hold charge of a brigade laboratory from 11 February 1943. On 9 July 1943, sanction was obtained to change the existing designation of brigade laboratory to station laboratory. The following revised establishment was also authorised :—

Major, captain or subaltern, IAMC or RAMC (from existing officer strength of hospital) ...	1
Laboratory assistant [(staff sergeant, WAC(I)] ...	1
Ward servant, grade I	1
Ward servant, grade III	1
Sweeper	1
Peon	1

The equipment of a station laboratory was provided on the scale laid down for brigade laboratory subject to minor modifications wherever necessary. The officer-in-charge was authorised a charge pay. Brigade laboratories at the following stations remained located at existing stations under their new designation of station laboratories—Abbottabad, Sialkot, Jubbulpore, Allahabad, Bhopal, Bannu, Ambala, Mhow, Delhi Cantt., Dehra Dun, Deolali, Kirkee, Yol (Kangra Valley) and Jhansi. Establishment of new station laboratories at other stations with 250 or more equipped hospital beds were to be considered on the merits of each case. Station laboratories were subsequently established at Jhelum, Nowshera, Vizagapatam, Coimbatore, Aurangabad, Belgaum, Jullundur, Mehgaon, Roorkee, Benares, Kanpur, Agra, Bareilly and Madras. By 1945, 46 such laboratories were raised.

The officer-in-charge, station laboratory, was required to do all clinical pathology work for hospitals in his station as well as any out-station hospital without laboratory facilities, and to keep in touch with the officer-in-charge of district laboratory. He was also required to submit annually a report on a work of his laboratory.

Serological Laboratories : In addition to the few district laboratories which carried out Wassermann and Kahn tests, two special serological laboratories were proposed to be established at the large venereal disease hospitals in armies/commands. One of these laboratories was actually established at Serampore. The officer-in-charge was a recognised specialist in pathology. The following establishment was sanctioned for this laboratory.

Major, IAMC or RAMC	1
Major, captain or subaltern	1

Sergeants, RAMC (laboratory attendants class I)			...	2
Clerical havildar, grade III	...	...	...	1
Ward servants, grade I ...	...	...	...	2
Ward servant, grade III	...	...	...	1
Sweeper, grade I ...	...	...	...	1
Sweeper, grade II ...	...	...	...	1
Clerk, civilian (locally engaged)		...	...	1

ARMY PATHOLOGY ADVISORY COMMITTEE

The Army Pathology Advisory Committee for India was formed and held its first meeting on 18 May 1944. The members of this committee included the following :—

DDH and P, GHQ—Chairman
Consultant surgeon, India Command
Consultant physician, India Command
Director, CRI, Kasauli
O.C., Central Military Pathology Laboratory, India
ADP, Eleventh Army Group, South East Asia
ADP, GHQ
ADP (Research), GHQ.

The committee could co-opt members if circumstances indicated the necessity for the attendance of experts on any particular subject. Subsequently, the field director MRC scrub typhus unit, a representative of Medical Advisory Division, SEAC, deputy director of pathology, ALFSEA, assistant director of clinical research GHQ and assistant director of malariology (ADM) (preventive research), GHQ were included in the committee. The terms of reference of the committee were to direct, co-ordinate and suggest research work to be carried out by pathologists in the India Command, and to advise on all technical and administrative aspects of clinical pathology in the India Command.

RESEARCH ORGANISATION IN INDIA

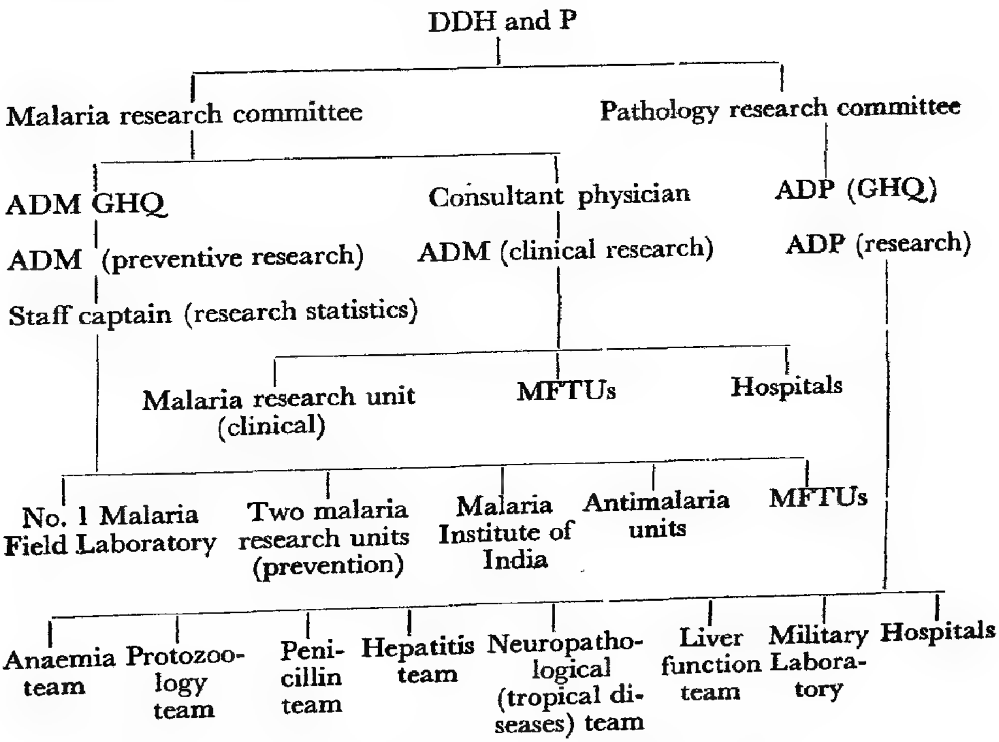
Prior to the outbreak of World War II, there was no separate military research organisation in India. Pathology and clinical research was carried out by specially selected officers of the IMS and RAMC, in addition to their ordinary duties, and necessary funds were placed at their disposal.

The main problems during the war in India and South East Asia which required urgent whole time research were: malaria, malnutrition and anaemia among IORs, protozoal dysentery, typhus fever, infective hepatitis, the neuro-pathology of tropical diseases and the use of new drugs, e.g., penicillin.

The most important function of the medical services of the armed forces is to prevent diseases and promote health. Certain amount of applied research, i.e., application of scientific principles to requirements is now considered to be an important function of the medical services. Medical research in the armed forces is essentially of an applied nature but certain amount of fundamental work has also to be undertaken.

Research organisation in the armed forces was based on these principles. Enquiries were instituted for those diseases and disorders which produced high morbidity or invalidment and mortality amongst the forces. The important need of the time was to find a quick solution for reduction of morbidity. While not many new scientific discoveries were made, yet as a result of these enquiries tangible results were achieved and large number of diseases were brought under control. The advances made in regard to diagnosis and treatment reduced the period of hospitalisation. A fair amount of fundamental knowledge was collected during these investigations, e.g., ecology and bionomics of vectors of scrub typhus and its epidemiology and aetiology, and treatment of sprue and anaemia, and the role of various haematopoietic factors in anaemia amongst the armed forces. It was also realised that organisation of research in any hospital raised the standard of medical attention due to the development of scientific outlook amongst the medical officers.

In order to put military medical research in India on a firm and scientific basis, it was necessary to organise teams controlled by whole time directors. Accordingly the following organisation was sanctioned in July 1944 :—



The malaria research committee consisted of :—

DDH and P
ADM (GHQ)
Consultant malariologist (GHQ)
Consultant physician (GHQ)

ADM Eleventh Army Group, SEAC
ADM (preventive research) was a co-opted member and acted as secretary.

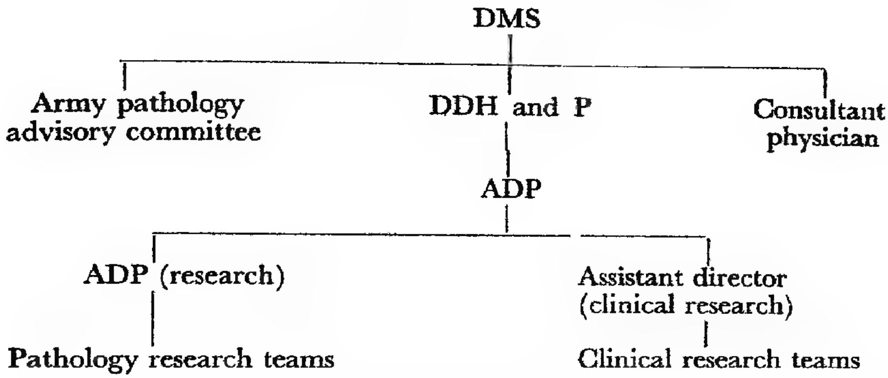
The pathology research committee consisted of :—

DDH and P
ADP (GHQ)
Consultant surgeon
Consultant physician
Director, CRI, Kasauli
ADP, Army Group, South East Asia
ADP (research) was a co-opted member and acted as secretary.

ADP (research) planned and co-ordinated all pathology research in India. He was responsible for the direction of the work of research teams and laboratories. He collated the results of published research work and modern research methods and advised how such methods and results could best be applied to research and clinical medicine in India. Under the new organisation a cadre of workers of requisite ability was built up and successfully employed. The undermentioned research teams were sanctioned and raised :—

Anaemia investigation team	21 December 1943
Penicillin research team	11 July 1944
Base typhus research team	11 July 1944
Field typhus research team	15 July 1944
Protozoal dysentery team	12 September 1944
Biochemical research team	12 September 1944
Parasitological research team	2 November 1944
Neuro-pathology research team	19 January 1944
Malaria research unit (clinical)	23 August 1944
War wounds research team	5 October 1944
Pool of laboratory assistants for research work	2 November 1944

It was soon realised that such *ad hoc* organisation had too many lacunae ; one was that as soon as the specific item of research was completed, the team stood automatically dissolved with its personnel dispersed. For a new problem to be investigated it was necessary to obtain formal administrative sanction which often caused delay and there was the additional difficulty of re-assembling the personnel. To obviate these difficulties and to render the organisation more elastic, a panel of research workers was formed. This arrangement ensured facilities for interchange of workers and consequently on 22 May 1945, the teams enumerated above were merged into a single unit. This organisation had a strength of 18 officers which included two lieut.-colonels, one to act as ADP (research) and the other as assistant director of clinical research. In addition, there were 58 other ranks including personnel of the IAMC, RAMC and WAC(I). This new organisation allowed for the formation of new detachments to undertake any specific problem. The organisation thus evolved is shown below :—



A marasmus research team was raised after discussion with a member of the MRC of the United Kingdom at a conference held at GHQ in June 1945. A sprue research team was also raised in July 1945 to carry out an investigation into the aetiology and treatment of sprue. By 25 November 1945, the establishment of GHQ medical research organisation was reduced to 15 officers and 47 other ranks. The establishment was further revised on 3 July 1946, and consisted of 6 officers and 23 other ranks only. Under this re-organisation no team functioned separately but the entire organisation was divided into four detachments which were attached to the units shown below :—

Detachment	Attached to
Base typhus research and field typhus research	Central Military Pathology Laboratory, Poona.
Sprue and nutritional research	BMH, Poona
Protozoology research	District Laboratory, Ranchi.

Later on the Central Military Pathology Laboratory absorbed the sprue and nutritional research and the base typhus research detachments. The Central Military Pathology Laboratory was itself absorbed in the Armed Forces Medical College in May 1948.

The various research teams submitted their reports to the GHQ where they were scrutinised, edited and published by the Medical Directorate research organisation. A summary of the work done by them is given below.[1]

Anaemia: Anaemia in Indian troops was one of the major problems of the Assam and Burma front. The anaemia investigation team examined healthy Indian soldiers and recruits, and their diets, in 1943. The major part of the problem was found to be essentially one of nutrition.[2]

[1] For details see Pathology Advisory Committee Reports, GHQ : *Report on Investigations on Anaemia in the Indian Soldiers* 1943-45 *and* 1945-46 (see also Volume on *Prevention of Diseases, Malaria Control and Nutrition* ; *Report on Investigations on the Marasmus Syndrome in the Indian Soldiers*, July 1945-March 1946 ; *Report on Sprue in India ; Report on Malaria Therapeutic Trials, Assam*, May and September 1946 ; *Report on Investigations on Arsenical Encephalopathy in Indian Troops*, 1943-1945 ; and unpublished reports on War Wounds, Schistosomiasis, Field Typhus, Base Typhus, Biochemical and Protozoology Research. See also report on *Scrub Typhus Investigations in South East Asia*, London, War Office.

[2] See also page 51.

Penicillin : The keeping properties of penicillin in the high temperatures encountered in India, formed the main subject of study by the penicillin research team, formed in July 1944. An apparatus for continuous administration of penicillin was also devised by the commanding officer of the team.

Typhus : A base typhus research team was formed and located in the Central Military Pathology Laboratory, Poona. The team was directed to develop methods of maintaining strains of rickettsiae isolated from outbreaks in different areas. The inter-relationship between different strains of rickettsiae isolated was studied and experiments concerned with isolation and maintenance of typhus strains by animal passage were carried out. A field typhus research team was also formed in July 1944, and was sent to Imphal to study the life history of those species of mite which were suspected of being carriers of scrub typhus and the ecology of all mites in relation to their part as vectors of typhus group of fevers. Investigations were also done on the relationship between the mite and the rodent on which the larvae of the mite lived and on transmission of rickettsiae by inheritance. This work received recognition in scientific circles.

Protozoal Dysentery: A team formed in 1944, investigated the various methods of treatment in amoebic dysentery.[3] Methods of culturing *entamoeba histolytica* were also studied.

Biochemical Research: The biochemical research team carried out investigation from 1944 to 1945 on possible toxic effects on the human body of suppressive mepacrine treatment. The study failed to show any evidence of adverse effects from suppressive mepacrine.[4] This view was not confirmed subsequently; some cases of psychosis have been recorded following mepacrine treatment.

Parasitological Research: An investigation team was formed in 1944 to determine the susceptibility of Indian molluscs to infection of *Schistosoma mansoni* and *Schistosoma haematobium.* The study showed that there was no possibility of Indian molluscs spreading human schistosomiasis in India.[5]

Marasmus: The marasmus research team was originally formed to draw clinical material for investigation from troops in the proposed Malaya Campaign. On the capitulation of Japan it was decided to examine the repatriated Indian POW.[6] The object of the research was :

(i) To examine clinically as many patients as possible with a view to obtaining a satisfactory classification of the various clinical states which may be associated with marasmus and also with a view to gaining as much information as possible concerning the aetiology, treatment and prevention of the condition.

(ii) To make a detailed clinical study of selected patients representing each of the main groups in the clinical classification, and to observe their progress and response to treatment.

[3] See also page 150.
[4] See also page 836.
[5] See also page 411.
[6] See also page 276.

(iii) To carry out a haematological investigation on these representative patients.

(iv) To make a study of the blood chemistry of the representative patients, including a study of the serum proteins, serum calcium, serum inorganic phosphorus, and serum phosphatase.

(v) To determine the blood volume and plasma volume of a smaller selected group of patients and, from these data to determine the total circulating haemoglobin, red blood cells and plasma protein ; to observe the rate of recovery in terms of the rate of production of haemoglobin, red blood cells and plasma protein and so to determine the pattern of recovery in marasmus patients.

(vi) To study the effect of transfusion of both plasma and whole blood to patients suffering from malnutrition.

(vii) To examine gastric function as represented by the fractional test meal findings and to investigate the effect of different treatments on those tests.

(viii) To investigate gastric function as represented by carbohydrate and fat tolerance test and to judge the effect of different treatment of these tests.

Sprue: In 1945, the sprue research team was formed.[7] The main objects of this investigation were:—

(i) To establish further understanding of aetiological factors by collecting the clinical data at the commencement of the disease and to classify its natural history particularly in the interpretation of the significance of the varied symptomatology.

(ii) To find out the state of fat absorption under controlled conditions in the disease.

(iii) To ascertain the therapeutic effects of liver and other substances under clinical laboratory control.

Malaria : A clinical research team evaluated various regimes of mepacrine therapy and compared them with the standard treatment of malaria at the time. Trials were carried out from May to September 1944 in Assam. As a result of this trial, courses of treatment for uncomplicated malaria were evolved.[8]

War Wounds : This team worked for about a year, mainly on ununited and infected fractures. Its main findings were :—

(i) That where penicillin was administered early in the front line gram positive organisms were less than gram negative organisms in the wounds.

(ii) Penicillin in inadequate doses in forward areas though reducing the incidence of *streptococcus pyogenes* infection by one-third, raised the rate of resistance of *staphylococcus* by one-third.

(iii) Penicillin resistant strains of *staphylococcii* in the wounds, sometimes occurring naturally, contra-indicate the use of penicillin.

(iv) Instillation of penicillin by narrow-bore rubber tubes was inadvisable as it afforded greater chances of secondary infection.

7 See also page 418.
8 See also page 267.

Neuropathology : The team carried out investigations on arsenical encephalopathy[9], malaria and cerebral thrombosis. It was observed that bi-weekly injections of arsenic had a significant influence on the incidence of encephalopathy.

CONFERENCES

From time to time pathologists like other specialists met in conferences of their own, in addition to attending joint meetings with other specialists.

In February 1944, a conference of medical specialists was held at Lahore. The subjects discussed covered the whole field of medicine. Typhus fevers were brought up prominently as were malaria, mental diseases, amoebiasis, enteric fevers, tuberculosis, psychiatry and training of specialists. The civilian teaching staff of the Lahore Medical College participated in this conference.

Another conference of physicians and pathologists was held in November 1944 at Agra. Anaemia was the theme of discussion and it was discussed from the angles of 'the soil' and 'the seed' followed by a critical survey of treatment and pathology. Concurrently with this there was a conference of pathologists where laboratory procedures relevant to anaemia were also discussed and demonstrated. Among the interested visitors were the teaching staff of the Agra Medical College.

The conference of pathologists in October 1945, at Poona had the privilege of having Professor E. J. King, Professor of Biochemistry at the University of London as a guest. The whole field of colorimetry photoelectric colorimetry and photometry was covered and Professor King gave several demonstrations of micromethods of biochemical estimations.

In addition to these purely professional meetings, the pathology advisory committee met at Delhi from time to time and their deliberations gave shape to many of the technical directives and medical administrative instructions.

TRAINING

In peace time the training of officers was generally conducted in Royal Army Medical College, Milbank after senior officers course and training in district and command laboratories. Officers were trained in district and command laboratories for three to six months, members of IMD for a year and other ranks for a year or two.

While this attachment for training sufficed in peace time, it was not satisfactory during the war. The Central Military Pathology Laboratory which was opened in 1944, was mainly established as a training centre. This ensured not only a greater number of trained personnel, but a uniform standard of teaching.

Training of Officers: Officers, who had an inclination or showed an aptitude towards pathology, were screened in the first instance in one

[9] See also page 79.

of the laboratories in India or abroad. They were then attached for four months training at the Central Military Pathology Laboratory. The training consisted of systematic lectures, demonstrations and practical classes in the various aspects of clinical pathology. The syllabus was modified from time to time and by 1947 it virtually covered the syllabus of diploma in clinical pathology or laboratory science of the universities. The officers were attached full time to this department and advantage was taken of the proximity of the Military Hospital, Poona for clinical material. In 1944-45, there were, in addition, several hospitals in the Poona-Kirkee area. In the period 1946-48, the officers after four months training at the Central Military Pathology Laboratory were attached to command or area laboratories for a further period of three to four months to allow them to gain more experience ; after this period they were considered for grading. There were intensive refresher courses for a large number of officers during 1944-45. The total number of officers trained in pathology in Central Military Pathology Laboratory from 1942-48 was 86.

Training of Laboratory Assistants : Training of laboratory assistants before World War II was neither centrally organised nor very strictly supervised, and the cadre as such did not exist except for the RAMC laboratory assistants. In the Indian Army, the work of laboratory assistants and technicians was performed by members of IMD and the cadre of ward servants. The former were generally licentiates in medicine and the latter were trained in military laboratories.

During the war a very large number of the members of the IMD were granted emergency commission in the IAMC and they were given the same training in pathology as officers of the IAMC. The ward servants, however, were grouped under a new heading—laboratory assistants. Recruits for the cadre were taken also from nursing orderlies class III or directly from the civil, the latter being men of some education and training in science.

The ward servants with experience in laboratory procedures were graded as laboratory assistants class IV from where they could advance in the cadre. New entrants were put through preliminary training lasting from three to six months and they were generally graded as laboratory assistants class III at the end of this period of training. A further experience of not less than six months in large laboratories generally entitled them to the grade of laboratory assistants class II, thereafter, one year's experience could make them laboratory assistants class I. It was quite clear that this was rather a haphazard method of training and promotion. Towards the end of 1945, therefore, a systematised method of training of laboratory assistants was undertaken. The syllabus for all the three classes of laboratory assistants was modelled on that of the *RAMC Training Manual*.

Towards the end of 1946, it was felt that the training in the three classes of laboratory assistants was not sufficiently exhaustive. In 1947 the following six classes of laboratory assistants were instituted and the syallabus was revised.[10]

[10] AI (1) 39/S of 1947.

Laboratory assistant, class III (lowest grade)
Laboratory assistant, class II
Laboratory assistant, class I
Laboratory technicians, class III
Laboratory technicians, class II
Laboratory technicians, class I (highest grade)
Command laboratories trained laboratory assistant, class III.

PATHOLOGY ORGANISATION IN THE FIELD

In order to provide pathology service in the field to the forces sent overseas, a new unit called the Indian field laboratory was created early in 1941. Field laboratories eventually formed the basis of pathology organisation in all theatres of war where Indian troops operated.

Field laboratories were raised in India as independent units; and as the units were small, they had to be attached to larger units such as general hospitals or CCSs for purposes of ration, accommodation and discipline. Otherwise, these units were completely self-sufficient in equipment and personnel and the officers commanding were responsible for maintenance of records and submission of weekly and monthly returns, in addition to their routine technical duties. The object of maintaining such independent status for field laboratories was to provide pathology service to more than one hospital or CCS at a time and to enable the units to be easily detached from one hospital and attached to another, whenever required.

Field laboratories were numbered serially and the total number raised in India was 60 including one Burma field laboratory. Of these, 17 saw service with the Middle East Forces, Central Mediterranean Force and Persia and Iraq Force; 31 served on Indo-Burma front and various parts of the SEAC and 12 served in India.

A field laboratory was designed to afford complete laboratory service to a general or base hospital. The original scheme was to provide one field laboratory for every two general hospitals plus one for each CCS. This was unlike the BGHs where a laboratory formed an integral part of each hospital. This scheme was obviously followed to provide economy in personnel and equipment so that maximum pathology service could be rendered with existing resources. But experience in Middle East soon showed that one field laboratory was incapable of carrying out the work of two or more large medical units (general hospitals and CCSs) even when these were grouped together. As the units were often scattered, they could not provide adequate laboratory cover. It was not till the end of 1942, that every Indian hospital was provided with a laboratory of its own.

The accommodation for field laboratories was often very makeshift, and some laboratories had to move constantly and often unnecessarily. The nature and amount of work varied, from clinical side room work to that of a complete pathology laboratory including histo-pathology and advanced serology. In addition, the officers often carried out the routine duties of hospital.

The equipment was ample, and certain cumbersome items, such as the Bara glass still, meant to provide specially pure distilled water, was rarely needed in the field. For all practical purposes the treatment of syphilis could be based on the results of Kahn test, and the Wassermann test was rarely necessary. The main criticism of the equipment provided was that too many items were issued, that some of the apparatus could not be used in the field, and that even the utmost care in packing could not prevent breakage.

The tentage provided was barely sufficient for laboratory purposes. Hence there was always overcrowding and most laboratories had to scrounge round for more accommodation.

Replacements were well arranged, and there was never any serious delay in meeting indents for medical as well as RIASC stores and transport. It was remarkable how willing people were to help as long as they were in the field, and quite often articles were supplied just across the counter.

A tendency to increase paper work was discouraged early in 1942, and the only reports that the field laboratories had to submit were the daily and weekly strengths, a brief monthly report and the war diary. As the field laboratories were very small units, the change in personnel was infrequent. In some areas, therefore, the daily and even the weekly returns were not insisted upon, and only the changes were notified.

The status of field laboratories as independent units was sometimes misunderstood by officers commanding hospitals, and often there was a tendency on the part of hospitals to swallow the laboratories. This led to unpleasant situations. The overzealous pathologist and a tactless officer commanding or vice versa, could make things difficult for all concerned. As these awkward situations became too frequent, the status of a field laboratory was made clear by a circular letter issued by Headquarters, Middle East Forces in April 1942.

The abuse of the laboratory was often due to inexperience of medical officers and led to inefficiency. The liaison between the pathologist and the physician, so desirable for the benefit of the patient, was unfortunately not always established in all cases.

Field Laboratories in the Middle East, the Persia and Iraq Force and Central Mediterranean Force : The field laboratories that were raised during the earlier years of the war, were sent overseas to serve with the Middle East and Persia and Iraq Forces. Later on they followed the advancing armies of the Central Mediterranean Force in Italy and Greece.

In Italy civilian laboratories were used at Taranto and Potenza. The Italian Royal Naval Laboratory at Taranto worked for No. 30 IGH from November 1943 to March 1944. A pathologist of No. 12 Indian Field Laboratory was given accommodation there with access to all facilities.

Considerable difficulties were experienced by some field laboratories in the Persia and Iraq Force and Middle East due to heat and dust storms. Besides, some of the laboratories were accommodated in tents without the provision of running water, which caused further difficulties.

Reagents, media and stains dried up completely and volatile reagents naturally volatilised. Cultures and stored media became quickly contaminated.

Many of the field laboratories had to improvise things for themselves. No. 2 Indian Field Laboratory found that paper petri dish covers, prepared according to instructions of the deputy director pathology Middle East Forces, were quite satisfactory. A home-made Kahn shaker was improvised by No. 7 Indian Field Laboratory. The problem of dark-ground illumination was solved by making use of Petromax lamp which proved a satisfactory substitute for electrical one. No. 12 Indian Field Laboratory improvised a faecal fat estimation apparatus. It also made a milk fat estimation set from salvage material. This laboratory was associated with work on dry blood test in typhus. (Bardhan, Tyagi, and Boutros, 1944) and on cold agglutinin (Shone and Passmore, 1943).

Field laboratories employed themselves successfully in research on local problems. Major J. H. Bowie, officer commanding, No. 10 Indian Field Laboratory, Baghdad, carried out investigations on an epidemic of typhus in Persia and Iraq Force. In June 1943, exanthematic typhus from 15 patients was established by passage in guinea-pigs and the strains were despatched by air to the Central Pathology Laboratory in Middle East. A report of the work done by the typhus investigation team was submitted to DMS, Persia and Iraq Force in October 1943. In April 1942, several typical clinical cases of typhus had been diagnosed. Positive Weil-Felix reactions were reported by No. 13 Indian Field Laboratory, Ahwaz. High titres to *Proteus OX*19 (1 in 5,000 or over) were obtained. Routine military pathology work at No. 17 Indian Field Laboratory, Tehran, was extended to cover typhus investigations of Persian civilian patients during the period April to July 1943. Similarly laboratory investigation of typhus cases formed the main feature of work at No. 18 Indian Field Laboratory, Dizful, during April and May 1943.

An investigation into relapsing fever cases occurring in the camps of Bhopal Sultania Infantry was carried out by No. 11 Indian Field Laboratory. A report on 43 cases of jaundice, accompanied with epithelial casts and albumin in urine, was submitted to the deputy director pathology Persia and Iraq Force by the officer commanding No. 18 Indian Field Laboratory, Dizful. Some of these cases showed MT malarial parasites while others did not. A few nutritional anaemia cases in vegetarian Jats were also investigated.

Field Laboratories in Indo-Burma Front and the SEAC : Some cholera cases were reported in the Arakan in May and June 1944. Water samples from various sources were tested by No. 49 Indian Field Laboratory. This was the only mobile laboratory available to the Eleventh Army Group. The Fourteenth Army asked for two mobile laboratories to investigate the outbreaks of typhus but the War Office clearly indicated that none would be available from European theatres, until the war with Germany was over. It was suggested that Indian field laboratories should be provided with a fitted 'Albion' mobile laboratory truck

similar to the type used by British mobile bacteriological laboratories. In July 1943, experimental work and investigation on typhus was undertaken by No. 34 Indian Field Laboratory in Gan Island (Maldives). A report of the investigation was sent to the DDMS, Ceylon Command.

A commission set up by the MRC arrived at Headquarters SEAC in July 1944. As a result of their deliberations, a scrub typhus research laboratory as an ALFSEA unit, was set up at Imphal. The GHQ Field Typhus Research Team merged with this laboratory in March 1945.

POST-WAR PATHOLOGY ORGANISATION OF THE SEAC

Though the war ended in August 1945, the troops serving under SEAC were scattered over a wide area for a considerable time after the cessation of hostilities. The distribution of laboratory services had, therefore, to be re-orientated. There were 17 laboratories serving under the command in September 1946. Most of the Indian field laboratories had by then been amalgamated with IGHs.

The following is a brief account of regional distribution of laboratory services in the SEAC.

Singapore District : No. 1 Central Pathology Reference Laboratory, Singapore was the military reference laboratory for the SEAC. Besides, it was a centre for manufacture of media, and biological reagents. It was equipped to carry out histopathological examination and serodiagnostic tests for syphilis. No. 47 BGH laboratory carried out routine work for No. 93 IGH.

Burma Command : Burma Command laboratory, Rangoon, was similar to that of Central Pathology Reference Laboratory. It also served No. 52 IGH and No. 91 IGH. There were four other laboratories, viz., laboratory of No. 58 IGH Rangoon, laboratory of No. 152 West African General Hospital, Rangoon, laboratory of No. 49 IGH Meiktila, and No. 1 Burma Field Laboratory which served No. 1 Burma General Hospital in Maymyo.

Malaya Command : There were three laboratories in Malaya Command, one each was attached to No. 72 IGH Kuala Lumpur, No. 45 IGH Johore Bahru, and No. 24 IGH Malacca.

Allied Forces Netherlands East Indies (AFNEI) : Five laboratories worked in AFNEI, viz., laboratory of No. 67 IGH Batavia, No. 32 Indian Field Laboratory serving No. 89 IGH in Batavia, laboratory of No. 124 IGH, Medan, No. 31 Indian Field Laboratory serving No. 24 CCS at Palembang, and one laboratory serving No. 48 and No. 54 IGHs.

Land Forces, Hong Kong : No. 57 Indian Field Laboratory served No. 28 IGH in Hong Kong.

British Troops, Siam : A laboratory formed part of No. 53 IGH in Siam.

British Troops, Borneo : Laboratory examinations were referred to No. 1 Central Pathology Reference Laboratory.

CLINICAL PATHOLOGY

By 1945, the number of pathology laboratories in India had increased to 99. Some of these laboratories had a short existence and were disbanded with the hospitals to which they were attached. A few of them did not even get an opportunity to function.

Detailed records of the work done by all the laboratories in India are not available. The following extracts from the *Annual Report on the Health of the Army in India* for the year 1945 may indicate the activities of clinical pathology service. Only a few of the activities of the laboratories, however, are mentioned below.

Enteric Group of Fevers[11] : A total of 13,040 blood cultures were taken from 8,437 suspected cases investigated during the year. Of these the infecting organism was isolated from 413. Out of the 413 positive cultures, 355 infecting organisms belonged to *Salmonella* group.

Bact. typhosum	238
Bact. paratyphosum A	90
Bact. paratyphosum B	4
Bact. paratyphosum C	8
Bact. enteritidis	11
Bact. enteritidis Var. dublin	1
Bact. morbificans bovis	1
Bact. typhimurium	2

Dysentery and Diarrhoea : A total of 74,662 specimens of faeces were examined and classified as follows :—

Bacillary exudate	6,598 (8·8 per cent.)
Indefinite exudate	11,840 (15·9 per cent.)
No exudate	56,224 (75·3 per cent.)

These specimens were also examined for the presence of protozoal infection with the following result.

Entamoeba histolytica (vegetative) ...	1,828
Entamoeba histolytica (cysts)	1,064
Balantidium coli	100
Flagellates	2,951

The type of helminth infections and the relative frequency of each type was as follows :—

Class—Trematode

Schistosomatidae ...	*S. mansoni*	132
	S. haematobium	63
Heterophyidae	*H. heterophyes*	1

Class—Cestode

		Adult	Ova
Taeniidae ...	*T. solium*	19	14
	T. saginata	215	275
Hmenolepididae ...	*H. nana*	2	107

[11] Also see page 388.
For analysis of 2,555 cultures of the *Salmonella* groups—see Appendix A, and for the value of agglutination tests for diagnosis of enteric group of fevers—see Appendix B.

Class—Nematode

			Adult	Ova
Strongyloidae	...	*S. stercoralis*	149	166
Tricharidae		*T. trichiura*	...	1,905
Ancylostomidae	...	...	47	7,469
Trichostrongylidae	...	...	14	38
Oxyuridae	...	*E. vermicularis*	31	182
Ascaridae	...	*A. lumbricoides*	14	3,434
Filatrididae	...	*W. bancrofti*	54	...
Dracunculidae	...	*D. medinensis*	1	...

The total number of Wassermann tests carried out during 1945 is given in the following table :—

TABLE I

Total number of Wassermann tests carried out during 1945.

	Total	Positive	Doubtful	Negative	Anti-complementary	Haemolysed or septic
Blood sera	249,001	61,005 (24·5 per cent.)	14,980 (6·0 per cent.)	161,851 (65·0 per cent.)	1,741 (0·7 per cent.)	9,424 (3·8 per cent.)
Cerebro-spinal fluid	5,504	425 (7·7 per cent.)	202 (3·7 per cent.)	4,656 (84·6 per cent.)	14 (0·2 per cent.)	207 (3·8 per cent.)

CENTRAL MILITARY PATHOLOGY LABORATORY, POONA

It may be recalled that the work of this laboratory mainly consisted of acting as central reference laboratory, training of officers and laboratory assistants. Biological products and standardised suspensions and sera were prepared at the laboratory. The laboratory was also equipped to carry out research.

In 1945, 29 RAMC other ranks were trained as laboratory assistants. A number of IAMC ward servants were also attached for six months training. In 1946, 10 RAMC other ranks and 13 IAMC VCOs and other ranks were trained in laboratory assistants class I course. The specialist courses (each course lasting four months) in pathology were attended by 18 IAMC and 14 RAMC officers in 1945 and 36 IAMC and 6 RAMC officers in 1946.

Preparation of Biological Products : The issues of Wassermann and Kahn test products during 1945 and 1946 to military laboratories in India are given below :—

TABLE II

Issues of Wassermann and Kahn test products during 1945-46.

Products	1945	1946
Wassermann antigen	6,000 cc.	3,555 cc.
1 per cent. cholesterol solution ...	*	1,830 cc.
Amboceptor	*	345 cc.
Kahn antigen	25,000 cc.	5,850 cc.

*Figures are not available.

Standardised Suspensions and Sera : The following table illustrates the issue of standardised suspensions for 1943-46. All the suspensions included in the figures given below had been concentrated, i.e., standard X15, to contain 6,000 million organisms per cc.

TABLE III

Issues of standardised suspensions during 1943-46.

Suspensions	Volumes in cc. issued during			
	1943	1944	1945	1946
Salmonella group ...	*	80,880	41,500	24,520
Proteus group	*	80,950	48,350	31,520
Dysentery group	*	1,050	...	...
Brucella group	*	10,740	3,300	3,534
Total	79,412	173,620	93,150	59,574

*Figures are not available.

Similar figures for diagnostic high titre antisera are shown in Table IV.

TABLE IV

Issues of diagnostic high titre antisera during 1943-46.

Antisera	Volume in cc. issued during			
	1943	1944	1945	1946
Salmonella group ...	*	11,260	9,560	4,930
Dysentery group	*	9,150	6,350	3,505
Cholera polyvalent ...	*	1,010	760	450
Brucella group	*	840	270	25
Proteus OX group ...	*	490	315	...
Total	20,408	22,750	17,255	8,910

*Figures are not available.

It will be seen that issues were largest for the year 1944, when the expansion of pathology laboratory services reached its maximum. During this year, two-fifths of total volume of suspensions were supplied to field laboratories. In addition, issues of suspension and sera were made to base medical stores, Persia and Iraq Force and to the United States Army. The laboratory also acted as a central reference laboratory. During 1945, 773 cultures of enteric and other groups of organisms were received from military laboratories in the India Command and the SEAC. A comparison and classification of these organisms are given in the following tables :—

TABLE V

Comparison between the number of strains of Bact. typhosum *and other* Salmonella *isolated.*

Year	Strains of *Bact. typhosum*	Strains of other *Salmonellae*	Total number
	Number	Number	
1941	166	72	238
1942	318	66	384
1943	394	170	564
1944	410	239	649
1945	327	222	549

TABLE VI

An analysis of the more common types of Salmonellae *isolated.*

Organisms (excluding *Bact. typhosum*)	Number received for verification during					
	1941	1942	1943	1944	1945	Total
Bact. paratyphosum A ...	60	52	93	85	102	392
Bact. paratyphosum B ...	5	0	2	0	0	7
Bact. paratyphosum C ...	4	4	20	76	49	153
Bact. enteritidis ...	0	7	48	55	39	149
Bact. enteritidis var. *dublin* ...	0	0	2	11	8	21
Bact. typhimurium ...	3	3	2	10	10	28
Miscellaneous ...	0	0	3	2	14	19
Total	72	66	170	239	222	769

TABLE VII

Details of the other organisms isolated.

Organisms	1944	1945
V. choleræ		
Ogawa	18	126
Inaba	0	1
Bact. dysenteriae		
Shiga	0	2
Sonnei	0	5
Flexner I	1	0
Flexner II	1	1
Flexner IV	0	1
Flexner V	0	1
Flexner VI	5	7
Boyd I	0	4
Boyd II	0	2
P. 143	1	0
P. 274	1	2
Paracolon bacilli, *Bact. alkaligenes*, etc.	39	72
Total	66	224

Histological Examinations : The number of cases examined and number of blocks prepared during 1945 and 1946 are given below :—

TABLE VIII

Details of histological examinations and number of blocks prepared.

Histological examinations	1945	1946
Biopsies		
Number of cases examined	*	1,015
Number of specimens examined	1,226	*
Number of blocks prepared	1,536	1,594
Number of blocks and slides received for confirmation	567	53
Autopsies		
Number of cases	*	509
Number of specimens	569	*
Number of blocks prepared	2,062	2,320
Number of blocks and slides received for confirmation	310	26
Museum specimens		
Number of cases	*	100
Number of blocks prepared	*	184
Normal tissues (for instructional purposes)		
Number of blocks	*	124

*Figures are not available.

Assay of Penicillin for Potency: In 1945 and 1946, 285 and 598 assays respectively of different batches of penicillin were performed. *Staphylococcus* N.C.T.C. 6,571 and Provisional British Standard Calcium penicillin were used for assay purposes. Standard methods were used. The findings were expressed in total unitage and unitage per mg. Experiments were also carried out to evaluate other methods used in penicillin assay. An ingenious apparatus was invented by Major M. D. Borcar for the application of Heatley cups to agar plates which ensured greater accuracy and saved time.

In addition to routine assays, investigations were also carried out by the penicillin branch of the laboratory during 1945-46 on the suitability of penicillin and of rubber tubing of Indian manufacture for administration of penicillin by the drip method.

Penicillin Research : The use of penicillin in Indian Army began in latter part of 1943. As the quantity supplied was very limited, it was reserved mainly for battle casualties, particularly on Burma front. In 1944, the supply position being slightly better, army hospitals were provided with penicillin to be used for selected cases.

In the middle of 1944, efforts were made to study the effects of penicillin therapy on a scientific basis and also to investigate various problems concerning the different aspects of penicillin. A war wounds research team and a penicillin research team were raised at Secunderabad to carry out the necessary research. These teams were instructed to train the medical officers in use of penicillin.

The war wounds research team at Secunderabad was engaged in investigating the effects of penicillin therapy in battle casualties coming from Burma front. The team worked for a period just over a year. The cases studied were generally ununited or mal-united fracture.

The bacteriological studies revealed the presence not only of the common pathogenic bacteria but also of some other organisms. This is summarised below :—

TABLE IX

Bacteriological studies of the war wounds research teams.

Micro-organism	Cases in which the organism appeared	
	Number	Percentage
Strep. pyogenes	18	27·7
Staph. aureus	25	38·5
Ps. pyocyanea	13	20·0
Proteus group	35	53·8
Coli-Aerogenes group	7	10·7
Diphtheriod group	23	35·4
Strep. viridans group	6	9·2
Staph. albus	5	7·7
Other organisms (non-pathogenic)	3	4·6

The results of penicillin therapy are shown below :—

TABLE X

Results of penicillin therapy.

Wound Group	Number of cases		
	Success	Failure	Total
Sterile	2	0	2
Gram positive	11	1	12
Gram negative	13	16	29
Mixed	15	18	33
Miscellaneous	1	0	1
Total	42	35	77

With the help of the REME an apparatus for administration of penicillin was devised. This apparatus consisted of a 2 cc. syringe mounted on an aluminium plate which could be fixed to the patient by short straps of elastoplast. The piston of the syringe moved in it by

means of a sliding block which was driven by a lead screw. The lead screw was rotated by an electric motor through a speedometer cable. The number of rotations was so arranged that the syringe discharged completely in 24 hours. The needle is partly coiled to impart flexibility. It was attached to the syringe by inter-position of a three-way tap. One of the openings of the tap is used to charge the syringe (Bowie and Borcar, 1947).

Other investigation done by the team was to confirm the findings of other workers as applied to Indian conditions. It was shown that extremes of temperature in India caused deterioration of penicillin during transport. With the end of the war in 1945, the work of war wounds research team came to an end for want of patients. Consequently, the war wounds research team was disbanded by the end of 1945, and penicillin research team was disbanded by March 1946. Penicillin research, however, was continued in Central Military Pathology Laboratory.

The early supplies of penicillin were not as pure as they are today. They used to deteriorate after certain period, during transport and by inefficient storage. In order to prevent the use of deteriorated penicillin, Central Military Pathology Laboratory, Poona, undertook the necessary assaying of all penicillin samples whenever it was found that the period prescribed by manufacturers had expired or when the clinical results of penicillin therapy were found unsatisfactory or when there was any doubt as to the continued potency of the drug. The method of assay employed in the laboratory was that described by Dr. N. G. Heatley of Oxford.

This method, though not accurate, was the only one available at that time. It allowed an error of as much as 20 per cent. in the values. Consequently, a loss of penicillin of about 20 per cent. had to be suffered to allow for the error. In 1946, as stated above, Major Borcar devised an apparatus by which the Heatley cups could be set mechanically on the agar plate. This improvement in the technique led to better accuracy in the results, by decreasing the error to less than 5 per cent. With the help of the apparatus the Central Military Pathology Laboratory was able to standardise the assay of penicillin giving reasonably reliable results, to save the 20 per cent. penicillin which had to be wasted for the allowances, and also to save laboratory material.

The Central Military Pathology Laboratory trained selected pathologists in laboratory control of penicillin therapy. It maintained the international standards used in connection with penicillin work and investigated the suitability of different preparations of penicillin and other antibiotics. It prepared creams and lozenges for local therapy.

With the increase in supply and decrease in battle casualties, the army medical authorities were able by the end of 1946 to allow the use of penicillin in different diseases and specifically in venereal diseases centres.

To conclude, it may be said that military authorities kept utmost vigilance and exercised rigid control on the distribution of penicillin so that the drug could be used to its maximum advantage. The army

was also responsible for teaching a number of civilian doctors in the use of penicillin and contributed in no small measure to general research on the subject.

Advance in pathology is necessarily linked up with advance in other sciences. The two world wars have increasingly emphasised the vital importance of planning of executive details in scientific research as well as in military operations. Today the tendency rightly is to express our spirit in organisation which ensures that planned research is undertaken and that attacks on problems are made along paths deliberately calculated. Such an approach to the subject has now been accepted by almost all countries. In India too the lesson has been well learnt that planning in pathology will produce surer and more lasting results than the sporadic attempts of individuals. The ability of the pathologists must be harnessed and geared to specific needs of the armed forces.

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APPENDIX A

Analysis of 2,555 Cultures of the Salmonella Groups

One of the many functions of the Enteric Laboratory, Kasauli, which was later amalgamated with the Southern Command Laboratory, Poona, to form the Central Military Pathological Laboratory, was the identification or confirmation of cultures mainly of the *Salmonella* group. The cultures were received from most of the military laboratories in the India Command and the SEAC. The figures for the period under review show the state of affairs among the armed forces serving in these areas from where the cultures were received.

A total of 2,555 cultures of the *Salmonella* group were received. It was expected that many more organisms of this group should have been sent either for confirmation or identification. This was probably due to many laboratories not fully utilising the services of this unit. Perhaps facilities did not exist for the bacteriological diagnosis of fevers of the enteric group in these laboratories for some time.

TABLE I

Identification of cultures at Enteric Laboratory, Kasauli, later Central Military Pathology Laboratory, Poona.

Cultures	1939	1940	1941	1942	1943	1944	Total
Bact. typhosum ...	103	140	208	318	394	410	1,573
Bact. paratyphosum A ...	39	61	292*	52	93	85	622*
Bact. paratyphosum B ...	4	3	90*	3	2	...	102*
Bact. paratyphosum C ...	...	1	4	5	20	76	106
Bact. enteritidis ...	...	...	...	5	48	55	108
Bact. dublin ...	...	...	2	2	2	11	17
Bact. typhimurium ...	1	1	3	1	2	10	18
Bact. virchow ...	...	...	...	...	1	1	2
Bact. litchfield ...	...	...	...	...	...	1	1
Bact. anatum ...	...	...	...	...	2	...	2
Bact. cholerae-suis ...	...	...	...	...	1	...	1
Bact. cholerae-suis Kunzendorf	...	...	...	...	2	...	2
Bact. reading	1	...	...	...	...	...	1
Total	148	206	599	386	567	649	2,555

* The increase in number of para-infection was due to the large number of Italian POW who were not immunised with TAB vaccine made in India. It is doubtful if they received any protective inoculation at all.

It will be seen from Table I that the figures for 1939 represent the normal incidence of the typhoid-paratyphoid group of organisms that used to be received in Enteric Laboratory just prior to the war. As the war progressed, this number—148—rose steeply until 1944 when 649 cultures were received. This increase in number was due to

the influx of troops from abroad and also to the Italian POW from the Middle East.

Most of the organisms received were *Bact. typhosum*, viz., 1,573 out of a total of 2,555 organisms sent to this unit for identification or confirmation. All these strains of *Bact. typhosum* gave the classical biochemical reactions of this organism. Serologically they were in the V-W phase and were non-motile on receipt To induce motility these organism had to be subcultured on 0·5 per cent. nutrient agar. After being subcultured the organisms became motile and the Phase I antigen of the organism could be determined.

The incidence of *Bact. typhosum* infection was 208 in 1941. This figure is inclusive of the cultures of *Bact. typhosum* (42) isolated from the Italian POW.

The infectivity rate for *Bact. paratyphosum A* was 622 for the total period, the peak incidence being during 1941 when 292 cultures were received. This sudden rise was again attributable to the Italian POW who accounted for 232 cultures of this organism out of the 292 cultures sent to this laboratory for confirmation.

Four anaerogenic strains of *Bact. paratyphosum A* were received. It may be mentioned that many anaerogenic strains lose this characteristic when cultured in broth sugar medium instead of peptone water. These four anaerogenic strains of *Bact. paratyphosum A* became aerogenic when cultured on this type of medium. It is considered that no strain should be termed 'anaerogenic' until the organism has been cultured in this alternate sugar medium.

The strains received were all motile and, therefore, did not necessitate the use of semi-solid agar. However, a peculiar strain of the organism was received which was not motile and remained so in spite of the fact that it was cultured on semi-solid agar. On serological examination, this strain possessed the somatic antigens I, II, XII. Further, on animal inoculation, no flagellar agglutinins could be elicited. This strain is of interest, especially to those engaged in the preparation of diagnostic *Bact. paratyphosum* A 'O' antigens as well as antiserum.

Another strain of *Bact. paratyphosum A* received was not motile on receipt. This strain was grown on semi-solid agar and the resultant organism, although motile, was not agglutinated by *Bact. paratyphosum A* 'H' antiserum. The organism was plated out into solid medium and colonies were cultured in nutrient broth. All the broth cultures were readily agglutinated by *Bact. paratyphosum A* 'H' antiserum.

Although *Bact. paratyphosum A* is a monophasic organism, it is felt that the inagglutinable organism was at the time in Phase II and reverted to Phase I after subculture on solid medium. In this connection, it may be mentioned that Bruner and Edwards (1941) isolated an alternate phase of *Bact. paratyphosum A* by culturing the organism on semi-solid agar in the presence of its homologous 'H' antiserum.

A total of 102 cultures of *Bact. paratyphosum B* were received. It is unusual to isolate this paratyphoid organism in India and the

normal incidence of infection by this organism varies from nil to four per annum. However, in 1941, 90 cultures of *Bact. paratyphosum B* were received. Five were isolated from personnel in the Army in India and 85 from Italian POW. In 1942, there was no incidence among these prisoners indicating that the infection was controlled due to effective immunisation with TAB vaccine prepared in India.

It may be added that phenolised TAB vaccine as used for immunisation of the armed forces has stood the test of time in India both in peace and war and it has still to be proved whether an alcoholised vaccine affords better protection than a phenolised one. It may be noted that workers elsewhere have concluded that there is little to choose between a phenolised and an alcoholised vaccine and as these workers were already manufacturing phenolised vaccine for mass immunisation they were not prepared to switch over from a phenolised to an alcoholised vaccine.

All troops arriving in India from abroad were immunised against the enteric group of diseases by the use of TAB vaccine prepared in India ; this further reduced the infectivity rate by organisms of the enteric group.

Another rarity among the organisms received was *Bact. paratyphosum C*. The peak incidence figure for this organism was in 1944, when 76 strains of *Bact. paratyphosum C* were received. All the strains were agglutinated only to a fraction of the titre by *Bact. typhosum* Vi serum. It was occasionally found that a strain did not contain this antigen after 24 hours incubation : if this organism was tested for the Vi antigen during the logarithmic phase of growth, Vi antigen was invariably present.

Biochemically all the strains of *Bact. paratyphosum C* fermented rhamnose and not arabinose thus further distinguishing *Bact. paratyphosum C* from a diphasic strain of *Bact. cholerae-suis*.

Two strains of *Bact. paratyphosum C* were found not to be motile on receipt. These strains possessed the distinguishing somatic antigens VI, VII and further contained the Vi antigen. Even after subculturing on semi-solid agar the organism proved to be deficient of flagellae. Animal inoculation did not indicate the presence of 'H' agglutinins. These strains are also of interest to individuals engaged in the preparation of diagnostic antigens and antisera as use of any of these non-motile strains will avoid the use of alcohol for the preparation of *Bact. paratyphosum C* 'O' antigen.

Another organism which has been the source of enteric-like fever in the India Command and the SEAC was *Bact. enteritidis*. A total of 125 strains were received : 108 were found to be *Bact. enteritidis* type *Chaco* and 17 were *Bact. dublin*. Two organisms were received from Quetta in 1942 : they were isolated from the blood and faeces of a calf and were identified as *Bact. dublin*.

The biochemical findings were interesting in that *Bact. enteritidis* type *Chaco* took five days at least to ferment dulcitol, whereas *Bact. dublin* fermented this carbohydrate within 24 hours. Another finding during these investigations was that the *Chaco* strains fermented both rhamnose

and arabinose, whereas *dublin* strains fermented rhamnose only. All the strains, with one exception were aerogenic. The anaerogenic strain was at first considered to be *Bact. typhosum* except for the fact that it did not contain the Vi antigen thus distinguishing it from *Bact. typhosum*. Although this organism was cultured in broth medium containing the appropriate carbohydrate, no fermentation with gas occurred.

Most of the strains of *Bact. enteritidis* isolated were from blood cultures and in view of the invasive character of the organism, it was thought that the organism would contain an additional antigen, something like the Vi antigen which would condition the virulence of the organism. All attempts to isolate the additional antigen failed.

Other additional organisms of unusual interest were :—

Bacterium anatum : Two organisms of this type were received and they were both isolated from blood cultures. Some difficulty was experienced in identifying these organisms as there are other similar organisms in the group all possessing identical Phase I antigens but dissimilar Phase II antigens. *Bact. anatum* possesses the flagellar antigens, e.h., in Phase I while in Phase II flagellar antigens 1, 6 are present. On the other hand *Bact. meunster, nyborg*, and *vejle* all possess similar Phase I antigens as *Bact. anatum* but in Phase II contain the antigens 1, 5; 1, 7, and 1, 2, 3 respectively.

Bacterium virchow : This organism was isolated from a most unusual source, viz., a pneumothorax—the result of a gunshot wound. The organism possessed the somatic antigens VI, VII and the flagellar antigen in Phase I and 1, 2, 3 in Phase II.

Bacterium litchfield : The organism was recovered from the heart blood of duck in a poultry farm where the mortality among these birds was high. The organism contained the somatic antigens VI, VIII and the flagellar antigens Phase I : I, v., Phase II : 1, 2, 3.

Bacterium typhimurium : Eighteen strains of *Bact. typhimurium* were received. This organism is the usual cause of gastro-enteritis. Most of the organisms received were isolated from the heart blood, a few from the faeces and one from the vaginal smear of a bitch which was aborting. A case of fatal bacteraemia in a child was studied in detail and reported by Freeman, Bardhan and Bamford (1948). It may be mentioned that *Bact. typhimurium* is a natural pathogen of rodents among whom it causes a typhoid-like disease. In the case reported, the organism was isolated from the heart blood, meninges and spleen pulp.

An organism isolated by Major J. A. Boycott, RAMC from the stool of a West African in the course of a routine examination for enteric carrier was forwarded to this unit for investigation. This organism (Taylor, Hayes, Freeman and Anderson, 1948) proved to be a new *Salmonella—Salmonella chittagong*—and has the following antigenic formula :—

(I).III.X. (XIX). XXVI; b........................Z 35

Z 35 was an antigen till then not described.

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APPENDIX B

The Value of Agglutination Tests for Diagnosis of Enteric Group of Fevers

The clinical application of 'Widal' reaction in the diagnosis of enteric group of fevers came under strong criticism during the war. It was suggested that as the diagnostic value of the test was limited, it should be completely abolished as a routine diagnostic procedure and more emphasis should be placed on the isolation of the causative organisms. All the armed forces personnel are inoculated and re-inoculated with TAB vaccine. In all TAB inoculated individuals there is a rise of both 'H' and 'O' agglutinins in the blood. The 'H' titre rises very high and remains so for a long time. 'O' agglutinins also show a rise but the titre seldom goes above 1 in 160 and generally falls below that level within six months after inoculation. Diagnostic agglutination tests with 'H' antigens have got a definite value in the uninoculated individuals and can be depended upon to give a correct diagnosis of the infection, but in an inoculated individual the demonstration of 'O' agglutinin, (with its limitations), can only be relied upon for this purpose. The curious feature of 'O' agglutinins in *Salmonella*, typhoid, paratyphoid and sub-group infections is that they fail to show the specificity that one would expect from the antigenic structure of the organism according to Kauffmann—White tables. It has been observed by various workers that quite a number of bacteriologically proved cases show a high 'O' titre against other members of the group than the one responsible for infection. The experience in India has also confirmed these observations and, therefore, it can be stated that it is impossible to correctly diagnose the cause of fever from 'O' agglutination test alone.

The Felix method for Widal tests was adopted in the army laboratories in India just before World War II. The tests are carried out with standard suspensions prepared by the Central Military Pathology Laboratory and the end point (standard agglutination) is recorded as suggested by Felix. A directive on the technique and interpretation of results was issued by the Medical Directorate, GHQ to all laboratories. Records of 671 bacteriologically proved cases were collected for the purposes of this study from various laboratories in India for assessing the diagnostic value of these tests. No arbitrary titre can be selected at or above which the results of a single agglutination test can be regarded as positive in diagnostic sense and below which it can be treated as negative. The results should be evaluated in conjunction with the following considerations :—

(i) Date of TAB inoculation of the individual. A titre of 1 in 160 'O' is observed in recently inoculated individuals but falls to an appreciably low level within six months.

(ii) The stage of the disease at which the sample is taken, as the rise of agglutinins is progressive during the disease and falls rather rapidly during convalescence.

(iii) The natural level of agglutinins amongst the population.

(iv) The tests have been performed in accordance with the standard technique and reagents.

(v) Certain individuals fail to develop agglutinin or develop them in low titre or late during the course of convalescence.

The results of Widal in 506 cases of typhoid fever are given in Table I.

It can be seen that in majority of cases of typhoid fever a T.O. titre of 1 in 320 and above can be demonstrated whether one or repeated Widals have been carried out. It is also evident that a fair proportion (last column) varying from approximately 7 per cent. in cases in which three Widals have been done to 25 per cent. in other groups, do not show standard agglutination in dilution higher than 1 in 160. In small number of cases only the A.O. agglutinins were present in the arbitrary diagnostic titre (1 in 320) in cases of typhoid fever, but in all these cases the T.O. titre was higher than A.O.

Table II shows the analysis of results of Widal tests for cases of paratyphoid A, B and C. Approximately 67 to 87 per cent. *paratyphoid A* failed to show agglutination above a dilution of 1 in 160. It also shows that a fairly high proportion of cases develop high T.O. agglutinins, i.e., above 1 in 320. Paratyphoid B cases are too few, but in not a single case T.O. agglutinins could be demonstrated in high dilution. Paratyphoid C cases are too few for analysis; therefore, no inference can be drawn from the results.

Properly spaced and repeated Widals during the course of the disease and convalescence are more valuable than a single test. However, it is quite reasonable to assume that in an inoculated individual in whom the agglutinins develop as a result of infection a titre of 1 in 320 and over is suggestive of infection with one of these organisms, more so for a progressively rising titre for 'O'.

(i) A proportion of bacteriologically proved cases failed to develop agglutinins, i.e., no agglutination in dilution higher than 1 in 160. (Table I shows that approximately 20 per cent. of cases fall in this group and in these cases diagnosis cannot be made on the basis of Widal tests alone).

(ii) Generally the 'O' titre for the causal group of organisms was higher than for the heterologous organism, but there was considerable amount of overlapping of agglutinins.

(iii) While detection and measurement of 'O' agglutinin was helpful in the diagnosis of enteric infection, it had very little value for differentiating one type of enteric fever from another.

(iv) Only in the uninoculated could one rely on 'H' agglutination for differentiation of different types of infection.

(v) Vi strain of *Bact. typhosum* was also given a trial. The suspensions supplied were prepared from selected strains and were tested against standard agglutinating sera. The results achieved were, however, disappointing. Suspensions were generally unstable specially

TABLE I

Analysis of Widal in Typhoid.

Widal	Total number		1 in 20		1 in 40		1 in 80		1 in 160		1 in 320		1 in 640		Above 1 in 640		Cases in which titre remained 1 in 160 and below	
	TO	AO	TO	AO	TO	AO	TO	AO	TO	AO	TO	AO	TO	AO	TO	AO	No.	Percentage of total number
1st Widal	248	64	16	17	20	13	24	22	3	5	54	3	100	4	31	0	63	25·40
2nd Widal	182	82	7	30	6	21	16	15	3	9	24	3	86	2	40	2	32	17·58
3rd Widal	76	28	2	9	1	5	1	5	1	4	19	2	33	3	19	0	5	6·58
4th Widal	34	28	1	6	3	8	3	2	1	7	3	3	13	1	10	1	8	23·53
5th Widal	5	4	0	0	1	1	0	2	0	0	0	0	1	0	3	1	1	20·00

TABLE II

Analysis of Widal tests for cases of paratyphoid A, B and C.

Widal tests	Total number		1 in 20		1 in 40		1 in 80		1 in 160		1 in 320		1 in 640		Above 1 in 640		Cases in which titre remained 1 in 160 and below	
	AO	TO	AO	TO	AO	TO	AO	TO	AO	TO	AO	TO	AO	TO	AO	TO	No.	Percentage to total number
Paratyphoid A																		
1st Widal	168	15	82	0	32	2	31	4	4	3	7	3	10	3	2	0	149	88·69
2nd Widal	135	10	60	0	20	0	24	4	3	2	17	2	10	2	1	0	107	79·26
3rd Widal	56	14	21	0	8	0	9	1	1	6	7	3	7	1	3	3	39	69·64
4th Widal	24	6	13	0	5	1	2	0	1	0	1	2	2	2	0	1	21	87·50
5th Widal	3	1	1	0	0	1	0	0	1	0	0	0	1	0	0	0	2	66·66
Paratyphoid B																		
1st Widal	6	0	4	0	1	0	0	0	1	0	0	0	0	0	0	0	6	100·00
2nd Widal	4	0	3	0	0	0	1	0	0	0	0	0	0	0	0	0	4	100·00
3rd Widal	5	0	4	0	1	0	0	0	0	0	0	0	0	0	0	0	5	100·00
4th Widal	7	0	6	0	1	0	0	0	0	0	0	0	0	0	0	0	7	100·00
Paratyphoid C																		
1st Widal	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	...
2nd Widal	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	100·00
3rd Widal	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	...

in hot weather; therefore, conflicting reports were received from various laboratories in India where large number of these examinations were carried out. The use of live suspension was suggested but being a risky procedure it was decided, not to use it for diagnosis of cases of typhoid fever. Estimation of Vi agglutinin is a valuable measure for detection of carrier. Its routine use for diagnostic purposes was considered to be of doubtful value in India.

Due to strict enforcement of preventive measures and protective inoculations enteric group of fever is not considered an important military disease. The incidence rate during the war was not much higher than the peace time figures. Morbidity rate from this disease has been showing progressive fall in the Indian and British troops during the last 25 years. However, the disease is not so uncommon as may be evident from the statistics as quite a number of mild cases are likely to be missed.

The only certain way of diagnosing this group of fevers is by the isolation of organisms from blood, urine and faeces. With proper care, it is possible to get a positive bacteriological diagnosis in over 90 per cent. of cases. Blood cultures are generally taken late.

Table III gives data regarding the day of the disease in which the organisms were isolated from various sources in different infections. In cases of typhoid fever, majority of isolations were made from specimens taken at the end of or after the first week. It may be added that in quite a number of cases the day of the isolation has not been available. Contrary to the existing belief that organisms from stools and urine can only be isolated after the first week, it is apparent from the table that quite a few isolations were made in the first week as well. The same inference can be drawn from paratyphoid A cases. The break up of the number in Table III may not agree with the total as in some cases the organisms were isolated from blood as well as from urine or stools.

Closer liaison between the clinician and the pathologist is essential for early isolation of the organism and for the reduction of contamination rate of the blood culture.

Bacteriological diagnosis of this group of fever in the armed forces cannot be considered as an academic curiosity. The control by preventive measures depends to a great extent upon the correct diagnosis of the infection. During 1949, in Bengal and Assam there were large number of infections by *Bact. enteritidis* and *Paratyphoid C*. The former was a *Dublin* variant, and therefore, most probably the vehicle for transmission was cow's milk. *Paratyphoid C* isolated from the cases could not be distinguished antigenically from the organisms isolated from the ducks in that area. Due to the war time conditions pasteurisation of the milk and general hygiene left much to be desired in that area. An order was issued that all milk will be boiled before consumption. The Headquarters, Eastern Command also issued an order that duck's eggs would not be consumed as raw or in semi-cooked state. The inclusion of *Paratyphoid C* in TAB vaccine was also seriously considered. It is very difficult to produce positive quantitative evidence, but from the available statistics it can be stated that, as a result of these measures, the incidence of this disease came down to a negligible level.

TABLE III

Data regarding the day of disease in which the organisms were isolated from various sources in different infections—Enteric group of fevers.

Enteric group of fevers	Total number	SOURCE																							
		Blood								Urine								Stools							
		1st day	2nd day	3rd day	4th day	5th day,	6th day	7th and above	Date not recorded	1st day	2nd day	3rd day	4th day	5th day	6th day	7th and above	Date not recorded	1st day	2nd day	3rd day	4th day	5th day	6th day	7th and above	Date not recorded
Typhoid ...	506	3	1	26	40	38	34	249	102	0	0	0	3	0	1	9	7	0	0	0	0	4	2	8	8
Paratyphoid A ...	153	0	2	9	22	13	15	70	21	0	0	0	0	1	1	0	1	0	0	0	0	1	0	1	1
Paratyphoid B ...	10	0	0	0	0	1	2	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Paratyphoid C ...	3	0	0	0	2	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

In cases of paratyphoid infections, early blood culture is essential as bacteraemia in these infections is transient and occurs during the early part of the disease only. In cases of typhoid and enteritidis infections late isolations are quite common.

In inoculated individuals when bacteriological diagnosis cannot be established, the only method left for arriving at a tentative diagnosis is by Widal tests with 'O' antigens. So long as the limitations of the tests are realised, Widal tests have a definite place in the diagnosis of infections with *Salmonella*, typhoid, and paratyphoid sub-group.

Index of Medical Directorate, India, Technical Instructions Nos. 1-83

Medical Directorate, India, Technical Instructions Nos. 21 and 72 were not issued.

List of Important Pamphlets Issued by the Medical Directorate, Army Headquarters (India) During World War II

1. Aids to treatment of skin diseases commonly occurring in the Eastern Army area.
2. The disposal and treatment of the gas casualties.
3. Notes on clinical side room methods.
4. Culture media preparation.
5. Notes on clinical biochemistry.
6. Notes on histological technique.
7. Notes on the treatment of venereal diseases.
8. Antimalaria measures in military stations in India.
9. Lectures on antimalaria measures.
10. Prevention of malaria on field service.
11. A note on vaccination.

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